POR-2501
(WT-2501)

40

3-4

Operation

ROLLER COASTER

PROJECT OFFICERS REPORT—PROJECT 2.1

SOIL DEPOSITION

AD 477688

DDC FILE COPY

William S. Johnson, Sr.,
Project Officer

Eberline Instrument Corporation
Santa Fe, New Mexico

Issuance Date: January 31, 1966

~~OFFICIAL USE ONLY~~

POR-2501
(WT-2501)

(21) Report on

OPERATION ROLLER COASTER,

PROJECT OFFICERS REPORT — PROJECT 2.1.

(6) SOIL DEPOSITION.

(18) DASA, AEC

(19) POR-2501, WT-2501

(9) Project officers rept.,

(10) William S. Johnson, Sr.

~~Project Officer~~

(11) 31 Jan 64

(12) 96p.

Eberline Instrument Corporation

This document has been approved for public release and sale; its distribution is unlimited.

This publication is the author(s) report to Director, Defense Atomic Support Agency; Director, Division of Military Application, Atomic Energy Commission; and Director, Atomic Weapons Research Establishment, United Kingdom Atomic Energy Authority, of the results of atomic weapons experimentation sponsored jointly by the United States - United Kingdom. The results and findings are those of the author(s) and not necessarily those of the Department of Defense, Atomic Energy Commission, or United Kingdom Atomic Energy Authority. Accordingly, reference to this material must credit the author(s). [redacted]

[redacted]

[redacted]

~~OFFICIAL USE ONLY~~

ABSTRACT

The blast and throwout areas immediately surrounding the detonation points of the four Operation Roller Coaster events were investigated extensively for (plutonium radioactive isotopes) Pu^{239} deposition and distribution. Device placement and explosive yield differed for each but the last two events from a single device on a steel plate in the open to nineteen devices with two and eight feet of earth overburden. The amount of plutonium radioactive isotopes Pu^{239} available for dissemination was essentially constant for all events.

In the various mixtures of contaminant and metal, soil and concrete debris which resulted from such detonations, quantitative measurements by alpha detection were inadequate due to the limited range of the alpha particle. Unless a high degree of homogeneity was present in the debris, normal spot sampling techniques were likewise inadequate even with absolute determinations by radiochemistry. For these reasons the most reliable data were derived from large scale assays based on the electromagnetic radiations found in weapons grade Pu^{239}. Special instrumentation was fabricated with optimum sensitivity for these radiations. This instrumentation, with similar circuitry and detectors, was used to assay metal debris and to monitor large land areas. ~~Some correla~~tive factors have been obtained by radiochemistry for the conversion of instrument response to absolute (plutonium radioactive isotopes) Pu^{239} concentration.

The scavenging of Pu^{239} by metal surfaces following detonation became the subject of a special study as a result of early field date evaluations. These intensive investigations were known as the Roller Coaster Follow-On Project. In this project, exclusive use was made of gamma detection techniques including radioautography with correlative radiochemical analyses.

The assays of the debris indicated no real advantage from the scavenging action of eight feet of earth overburden compared with only two feet of earth overburden. A major factor in significantly improving the situation was the

use of metal throughout such structures as a substitute or facing for concrete. Optimization of this approach, e.g., selection of metal and its configuration, should be the subject of special research studies.

Under the most severe conditions of Operation Roller Coaster, the residual contaminated area of immediate concern, after cloud passage for monitoring contamination control, restricted access, etc., was less than 2,500 feet from GZ in the downwind direction and about 100 feet from GZ in the upwind direction. While accurate quantitative determinations are lacking, the conclusion appears valid that a surprisingly low percentage (less than 20 percent) of the total radioactive material exists in the debris and within 2,500 feet of GZ.

PREFACE

Project 2.1 was fortunate in obtaining the services of several agencies. Personnel from Mobile Construction Battalion Five, Port Hueneme, California; Disaster Recovery Training Unit and Mobile Construction Battalions One, Four, and Eight, Davisville, Rhode Island, participated in the field programs. Their contributions were most valuable. Major R. T. Trolan, CMLC, USA, assembled, trained, and coordinated these units into an effective field organization.

The Project Officer also wishes to acknowledge the several contributions, both in the field and laboratory phase and in the report preparation phase by Mr. Eric L. Geiger, Eberline Instrument Corporation, Santa Fe, New Mexico.

CONTENTS

ABSTRACT ---------- 5

PREFACE ---------- 7

CHAPTER 1 INTRODUCTION ---------- 13

1.1 Objectives ---------- 13
1.2 Background ---------- 13

CHAPTER 2 EARTH MINING ---------- 17

2.1 Instrumentation ---------- 18
2.2 Calibration ---------- 22
2.3 Procedures and Operations ---------- 24
2.4 Discussion ---------- 30
2.5 Results ---------- 33

CHAPTER 3 EARTH CORING ---------- 54

3.1 Instrumentation ---------- 55
3.1.1 Soil Coring Device and Tools ---------- 55
3.1.2 Detector and Electronics for Soil Core Scanning ---------- 61
3.1.3 Core Support and Indexing Mechanism ---------- 63
3.2 Calibration ---------- 63
3.3 Procedures and Operations ---------- 64
3.4 Discussion ---------- 65
3.5 Results ---------- 66

CHAPTER 4 EARTH THROW-OUT ---------- 83

4.1 Instrumentation ---------- 83
4.2 Procedures and Operation ---------- 84
4.3 Discussion ---------- 84
4.4 Results ---------- 85

CHAPTER 5 CONCRETE CORING ---------- 89

5.1 Instrumentation ---------- 89
5.2 Calibration ---------- 91
5.3 Procedures and Operations ---------- 91
5.4 Discussion and Results ---------- 91

CHAPTER 6 ALPHA SURVEY AND GAMMA SURVEY ACTIVITIES ---------- 100

6.1 General ---------- 100
6.2 Special Activities ---------- 101

6.2.1 Double Tracks ---------- 101
6.2.2 Clean Slate I ---------- 101
6.2.3 Clean Slate II and III ---------- 102
6.3 Discussion and Results ---------- 102

CHAPTER 7 FOLLOW-ON DEBRIS STUDY ---------- 116

7.1 Background and Objectives ---------- 116
7.2 Instrumentation ---------- 117
7.3 Calibration ---------- 119
7.4 Procedures and Operations ---------- 120
7.5 Discussion ---------- 123
7.6 Results ---------- 124
7.6.1 Double Tracks Steel Plate ---------- 124
7.6.2 Igloo Scavenging ---------- 127
7.6.3 Metallographic Studies ---------- 131

CHAPTER 8 CORRELATION, ACCOUNTABILITY AND DISCUSSION ---------- 152

8.1 Double Tracks ---------- 152
8.2 Clean Slate I ---------- 154
8.3 Clean Slate II ---------- 156
8.4 Clean Slate III ---------- 158

CHAPTER 9 CONCLUSIONS ---------- 160

APPENDIX A SOIL CORE DATA ---------- 162

APPENDIX B CALCULATION OF BELT MONITOR EFFICIENCY ---------- 243

APPENDIX C EVALUATION OF ALUMINUM DEBRIS ---------- 246

REFERENCES ---------- 250

TABLES

2.1 Plutonium in Soil from Mining Operation ---------- 36
2.2 Calibration of Belt Monitor ---------- 37
2.3 Comparison of Total Sample and Aliquot Counts ---------- 38
2.4 Comparison of Counts from Belt Monitor ---------- 41
2.5 Traverse of Belt Monitor with Am^{241} Source ---------- 43
2.6 Effect of Depth Distribution ---------- 44
2.7 Clean Slate II Mining Data ---------- 45
2.8 Clean Slate III Mining Data ---------- 46
5.1 Concrete Core Sample Data ---------- 93
7.1 Clean Slate II Event ---------- 134
7.2 Clean Slate III Event ---------- 135

FIGURES

2.1 Earth screening plant ---------- 47
2.2 Detector unit over belt showing support frame and position relative to soil- ---------- 48

2.3 Checkout of pulse height spectrum for belt scanner ---------------- 49
2.4 Earth mining equipment-- 50
2.5 Calibration of belt monitor by radiochemistry-------------------- 51
2.6 Skip loader clearing debris at edge of crater-------------------- 52
2.7 Traverse of belt monitor with Am^{241} source -------------------- 53
3.1a through f Soil coring procedures ----------------------------- 67
3.2 Checkout of pulse height spectrum for core scanner --------------- 73
3.3 Location of earth core samples, CS II ------------------------- 74
3.4 Core scanning equipment, Tonopah Test Range ------------------ 75
3.5 Location of earth core samples, CS III------------------------- 76
3.6a through e Core sampling team operations --------------------- 77
3.7 Core depth distribution data --------------------------------- 82
4.1 Plastic-lined collector in throw-out area ----------------------- 86
4.2 Throw-out sampling array, CS II ---------------------------- 87
4.3 Throw-out sampling array, CS III---------------------------- 88
5.1a and b Concrete coring procedures --------------------------- 94
5.2 Location of concrete cores, DT ----------------------------- 96
5.3 Location of concrete cores, CS I---------------------------- 97
5.4 Location of concrete cores, CS II ---------------------------- 98
5.5 Location of concrete cores, CS III---------------------------- 99
6.1 Close-in alpha survey, DT---------------------------------- 104
6.2 Close-in alpha survey, CS I--------------------------------- 105
6.3 Close-in alpha survey, CS II -------------------------------- 106
6.4 Close-in alpha survey, CS III-------------------------------- 107
6.5 Close-in gamma survey, DT -------------------------------- 108
6.6 Close-in gamma survey, CS I------------------------------- 109
6.7 Close-in gamma survey, CS II ------------------------------ 110
6.8 Close-in gamma survey, CS III------------------------------ 111
6.9 Gamma survey on DT concrete pad, steel plate, and close-in area ------ 112
6.10 Gamma survey of CS I concrete pad------------------------- 113
6.11 Concentric gamma survey by vehicle scanner, CS II-------------- 114
6.12 Concentric gamma survey by vehicle scanner, CS III -------------- 115
7.1 DT steel plate and concrete pad at GZ after detonation -------------- 136
7.2 Igloo debris as recovered at Tonopah Test Range------------------ 137
7.3 Field gamma scanning of igloo debris ------------------------- 138
7.4 Cutting igloo debris for radiochemistry samples ------------------ 139
7.5 PG-1 gamma cpm versus μg Pu^{239} by radiochemistry--------------- 140
7.6 PG-1 gamma cpm versus μg Pu^{239} conversion table --------------- 141
7.7 Scanning DT steel plate------------------------------------ 142
7.8 X-ray film on DT steel plate -------------------------------- 143
7.9 Radioautograph of DT steel plate---------------------------- 144
7.10 Dosimetry film on DT steel plate----------------------------- 145
7.11 Radioautograph of CS III igloo debris showing corrugation shadow effect-- 146
7.12 Comparison of DT steel plate section before and after decontamination -- 147
7.13 Gamma measurements of DT steel plate and concrete pad ------------ 148
7.14 Gamma measurements of DT steel plate before and after burial ------- 149
7.15 Photomicrograph showing loose, slag-like oxides---------------- 150
7.16 Photomicrograph showing oxides trapped in indentation------------- 151

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

Summarily stated, the assigned objectives of Project 2.1 were:

1. The collection and assay of soil and debris for contamination distribution and accountability.
2. The collection of debris and structure soil for separation chemistry.

These collections were concentrated in and around the crater, the blast area, and the throw-out area which was confined to the first 400 feet from ground zero (GZ).

Secondary objectives of the project were to assist in radiac surveys out to 2,000 feet from GZ in support of Project 2.5 and to determine the effectiveness of local scavenging action of the storage structures.

1.2 BACKGROUND

Preoperational studies of project objectives indicated that the success of total Pu^{239} accountability efforts

could depend heavily on the thoroughness with which measurements were made in the immediate vicinity of GZ. Cursory surveys with low energy gamma detectors around the GZ of previous plutonium releases at the Nevada Test Site (NTS) supported this opinion (Reference 1). Core sampling of the storage structure, soil sampling of outer areas, and use of throw-out-material collectors were considered as field expedients to accumulate reliable data. Each method relied on the assumption of a certain degree of homogeneity in the deposition pattern if extrapolation to total Pu^{239} was to be meaningful.

As one calculated the density of sampling locations to expose any significant perturbations from a uniform pattern, it became apparent that a reasonable fraction of the total material requirements as applied to Roller Coaster conditions indicated otherwise. A significant contribution to the resolution of the discussions was the experience of the uranium mining industry in New Mexico (Reference 2). Core sampling at density higher than proposed for Roller Coaster had been found to be inadequate for postulating ore body location and extent. Radioassay scanning of all mined material as it passed over

a moving belt proved to be a highly reliable solution. The extension of existing low energy gamma detection techniques to a similar scanner was made for Roller Coaster purposes.

Later, Operation Sideshow, an explosive test of an igloo storage structure conducted at the U.S. Naval Ordnance Test Station, China Lake, California, supplied additional supporting evidence for including a mining type operation. This test of a storage structure with 2 feet of earth cover revealed that material raised by the detonation, and presumably highly contaminated, falls back principally in and near the crater. This resulted in a heterogeneous mixture in the crater with a high probability of most of the contamination on the surface. After reviewing all of these experiences, it was decided to conduct Project 2.1 with both coring and mining operations with each supplementing the other in the development of the picture of Pu^{239} deposition.

The collection of structure soil for separation chemistry was an assigned objective to provide throw-out material for the laboratory investigations of Project 5.2. For this purpose it was desired that samples be obtained which

were free of dilution by the soil surrounding the structure. Wash tubs and pie pans were selected as collectors with the former used within 300 feet of GZ and the latter at greater distances. Collector efficacy and optimum positioning were evaluated during Operation Sideshow.

CHAPTER 2

EARTH MINING

Realizing the importance of accurately measuring the amount of plutonium mixed with earth overburden on certain Roller Coaster events, numerous methods were studied which had a potential application to the problem. In final evaluation, it was decided that the best method for obtaining this accountability was to mine the contaminated soil and use low energy gamma techniques for detection and measurement. This low energy gamma technique was also used for the vehicle mounted gamma scanners and the soil core scanning device.

The earth mining procedures for involved a new application of a technique developed by the Eberline Instrument Corporation in 1957 for the uranium mining industry. It was found that a gamma detection device optimized for U_{238} detection was more reliable and more accurate in determining the U_{238} content of a truckload of uranium ore than analyzing an aliquot by radioassay. In order to fit this technique to the requirements of Project 2.1, three basic pieces of equipment were required. These were a port-

able screening plant with a moving belt, counting and detecting equipment, and a front-end skip loader.

2.1 INSTRUMENTATION

The belt scanner system designed for Operation Roller Coaster was the only piece of special equipment required for the earth mining and plutonium assay. Basically the system consisted of a scintillation detector, counting electronics, and a portable screening plant for depositing a uniform layer of soil on a moving belt. The detector was placed above the conveyor belt and monitored the soil passing under it. The counting electronics used pulse height analysis to look at 17 and 60 Kev photons emitted from the Pu^{239} and Am^{241} mixed with the soil. The basic objective of the system was to determine the amount of Pu^{239} in a known amount of soil.

The detector design for the belt scanner was started concurrently with the detectors for the core scanner and the vehicle mounted gamma scanners, which were also to be used in Roller Coaster. Design of all three detectors was essentially the same for ease of field service and design simplicity. The detector was a 2 1/2-inch diameter by 1-inch-thick NaI (Tl) crystal with a 0.001-inch-thick aluminum window viewed

by a 3-inch-diameter DuMont 6363 photomultiplier tube. This was housed in a 2-inch-thick lead shield and had a maximum diameter of 11 inches. The shield had provisions for the addition of dry ice inside to cool the photomultiplier tube, although this feature was not used. A collimator was placed over the crystal which had a 90° included angle. This sees a circle approximately 28 inches in diameter with the detector face 15 to 18 inches above the soil on the belt. The preamplifier was mounted on the lead shield to be as close as practicable to the photomultiplier tube. The high voltage decoupling was increased and the input circuit was changed to be compatible with the photomultiplier tube circuit.

The screening plant was fabricated by N. C. Ribble and Company of Albuquerque, New Mexico. The screening plant is shown in Figure 2.1. The design criteria established for the screening plant were as follows:

1. Belt width of 30 inches.
2. Speed of moving belt will be variable from 1 foot per minute to 4 feet per minute. By changing sprockets, the speed may also be increased by

a factor of 4.

3. Capacity of hopper will be approximately 3 yd^3.

4. Motor driven shaker screen will be incorporated to remove foreign matter such as large stones, undergrowth, roots, and boards.

5. The hopper will be capable of depositing a uniform layer of soil on the moving belt. This layer shall be variable from 1 inch to 6 inches thick.

6. Power requirements will be 220 v/ac, 3-phase.

The counting equipment used in the mining operation was designed and fabricated by Eberline Instrument Corporation, using RIDL Designer Series modules. The detector for the system was suspended from a structural steel frame above the moving belt. The distance from the belt to the detector face was capable of being adjusted to the desired height by means of a telescoping frame incorporated in the supporting structure. The detector and its supporting structure are shown in Figure 2.2. This figure also illustrates the uniform thickness of soil on the moving belt.

The counting electronics for the mining equipment

consisted of the following:

(1) Preamplifier, RIDL Model 31-20

(1) Amplifier, RIDL Model 30-20

(2) Pulse Height Analyzer, RIDL Model 33-10

(1) H.V. Power Supply, RIDL Model 40-9

(2) Scaler, RIDL Model 49-28

(1) Timer, RIDL Model 70-10

(2) Cabinet and Power Supply, RIDL Model 29-1

The preamplifier was mounted on the outside of the detector. All other equipment was housed in a standard Emcor cabinet with the exception of the timer. The timer was used as a separate piece of equipment and could be placed at any convenient location near the counting electronics. All counting equipment was housed in a small 8-foot square building located approximately 300 feet from the screening plant. This building had an air conditioning unit installed for operator comfort and temperature stabilization of electronic equipment inside the building. Power for all equipment was obtained from a portable 25-kw motor generator set.

Preliminary checkout of all counting equipment and detector took place at the Eberline Instrument Corporation plant in Santa Fe, New Mexico, in April, 1963. A pulse

height spectrum was run at this time and is shown as Figure 2.3. Final threshold and window settings were made at the following points after confirming the spectrum with weapon grade material:

Channel 1 (Am^{241})	Channel 2 (Pu^{239})
Threshold - 60.0 Kev	Threshold - 10.0 Kev
Window - 20.0 Kev	Window - 20.0 Kev

The front end skip loader was a diesel-powered Michigan which was obtained from NTS at Mercury. The loader bucket had a capacity of 2 1/2 yd^3. Figure 2.4 shows the skip loader, screening plant, and detector in operation at the Roller Coaster site.

2.2 CALIBRATION

During the mining operation, several random samples of soil were taken from the belt and placed in plastic containers. The belt was stopped before each sample of soil was removed and counted for a period of one minute. After the sample was removed, a one minute background count was taken prior to re-starting the belt. Clean Slate II samples, 1 to 23 inclusive, represented an area 20 inches by 20 inches, per sample, directly under the detector, and all subsequent

samples represented an area 24 inches by 28 inches. The thickness of soil ranged from 1.0 to 2.5 inches and was measured for each run. The calibration sample was blended in six fractions, then 10% of each fraction was combined to obtain a 10% aliquot of the total sample. This aliquot was blended further and a 20-gram aliquot was removed for radiochemistry. Calibration factors based on these 20-gram aliquots are shown in Table 2.1 and Figure 2.5. The calibration factor based on the seven samples, for which the net Am^{241} count was greater than background, constituted the best value based on radiochemistry. This best value factor was:

$$18.2 \frac{\text{dpm } Pu^{239}/\text{g of soil}}{\text{belt cpm } Am^{241}}$$

Based on 15 g/curie, this factor can be expressed as:

$$0.12 \frac{\mu\text{g Pu/kg of soil}}{\text{belt cpm } Am^{241}}$$

After the field operations were completed, the validity of taking small soil aliquots was questioned. To obtain a calibration factor without taking small aliquots, the plutonium content of each 10% aliquot containing approximately 2 kg of soil was determined by gamma spectrometry. These results, tabulated in Table 2.2, provide a calibration factor

of:

$$0.16 \frac{\mu g\ Pu/kg\ of\ soil}{belt\ cpm\ Am^{241}}$$

The calibration factor was also calculated based on measurements with a 1-inch-diameter undegraded Am^{241} standard. The efficiency was measured in all four quadrants at 2-inch increments from the center of the area viewed by the detector. These efficiency values were weighted by area and corrected for self absorption to obtain an overall calibration factor. This [illegible]tor was $0.12 \frac{\mu g\ Pu/kg\ soil}{belt\ cpm\ Am^{241}}$ for both 20-inch and 24-inch widths of soil on the belt. This agrees with the calibration factor obtained by radiochemistry and is close to the value from gamma spectrometry (0.16). The details of the calculation are contained in Appendix B. This (0.12) is the factor used to convert counting data from the mining operation of plutonium.

2.3 PROCEDURES AND OPERATIONS

Operation of the mining and belt scanning equipment was confined to Clean Slate II and III events. Prior to the Clean Slate II event, the screening plant was transported

from base camp to a point 2,850 feet NW of CS II ground zero. The counting shack, detector, and motor-generator were placed 2,000 feet north of ground zero. Preshot checkout was performed on all electronic equipment at this point.

On D+2 of the Clean Slate II event, the mining equipment was moved into position. The screening plant was placed approximately 100 feet west of ground zero. The counting shack and motor-generator were placed 400 feet north of ground zero. Before actual mining could start, several large pieces of concrete debris had to be moved. These pieces were randomly located inside the crater entrance and were removed by a 5-ton crane. The skip loader was also utilized for clearing the area as illustrated in Figure 2.6. The rear concrete wall of the igloo was blown to the rear of th bunker and provided a convenient entrance to the crater since the east side was not easily accessible.

The skip loader started removing soil from the west outside of the bunker. One hopper load was run through the screening plant to check operation of all equipment. Background readings were taken and a check source was placed on the detector face to check calibration each time

the hopper emptied. The belt was moving at a speed of 4 feet per minute. After several hours of operation, it was decided that the belt speed was much too slow. The sprockets on the belt drive were changed after the fifth hopper load, and the belt speed was therefore changed to 16 feet per minute.

The following procedure was employed throughout the Clean Slate II mining operation:

Both hoppers of the screening plant were filled. The belt and shaker screens were started. When the soil on the belt was directly under the detector head, the counting electronics were started. After the top hopper was emptied, the belt, shaker, and counter were stopped. A 5-minute calibration count was taken of the soil directly under the detector. The soil which was counted was then removed from the belt and placed in a plastic bag and marked. The empty belt was then counted for 1 minute for background. A 1-minute count was taken with a check source against the face of the detector to verify calibration. The belt, shaker, and counting electronics were started again and run until the lower hopper was almost empty. At this time the equipment was stopped, the count and count time were recorded, and the hoppers

were filled again. Each hopper load was removed from a specific location, and this location was recorded. Communications between the screening plant operations and the coun..ng shack operations were maintained via portable radios. A summary of data taken appears in Table 2.7 for Clean Slate II and Table 2.8 for Clean Slate III.

Three days after the mining operation began on Clean Slate II, the background count started rising noticeably. It was discovered that small amounts of soil had been falling off the belt, causing an accumulation of contaminants on the ground under the belt. An area about 30 feet in diameter was scraped off. The background was reduced by a factor of 2. The ground immediately under the detector was kept clean from this time on.

All calibration soil samples were taken to the field laboratory for analysis to determine how much Pu^{239} was contained in these samples. The method and results of the above analysis are covered in a later section of this report.

The inside of the bunker was mined first to a depth

of approximately 18 inches. The entire inside of the crater was mined to this depth in a counter-clock-wise pattern starting at the extreme northeast corner. The outside of the crater was then mined in the same pattern as the inside to a distance of approximately 100 feet from ground zero. The hottest area found inside the crater was mined to a depth of 4 feet or more to determine if further activity existed. No significant activity could be found below the 18-inch depth mined on the first pass.

Operations on Clean Slate II were closed on June 9, 1963.

Operations on Clean Slate III were set up on June 10, 1963. The screening plant was placed on the west side of the bunker and the counting equipment was placed 350 feet northwest of the bunker. An area measuring about 50 feet square was scraped off before placing the screening plant to attempt to reduce background from debris and contaminated soil in the immediate area of the belt and detector. A small area was also graded off for the counting building. Light standards were fabricated and placed around the crater and mining

equipment so night operations could be accomplished. Twenty-four hour operation started on D+2 and continued through D+5 when Clean Slate III operations were completed. Procedures used on CS III were identical to those used on CS II except that fewer calibration samples were taken. This was permissible because it was necessary only to determine whether the ratio of cpm per yd^3 versus μgm of Pu^{239} per yd^3 for CS III was unchanged from the ratio found from CS II.

Figure 2.4 illustrates the mining equipment in operation on Clean Slate III. All mining operations were completed on June 14, 1963.

It is pertinent to mention rad-safe procedures used during the mining operation, since expected contamination levels could only be estimated. No definitive guidelines were available, since such an operation had never been carried out. The skip loader was outfitted with two air bottles and a Scott Air Pak for the operator. This apparatus was put in limited use on Clean Slate II and III. The dust hazard was not as severe as was originally anticipated. This was verified by negative nose swipes taken on all

mining personnel throughout the operation. All personnel wore full rad-safe dress which included two sets of coveralls, rubber totes, cotton booties, M-17 mask, cotton hood, surgeons gloves, and cotton gloves.

A crew of four men operated the mining equipment and counting electronics. Four shifts per day were run during 24-hour operations on CS III and two shifts per day were run during 12 hour operations on CS II.

One man operated the skip loader and assisted two other men working on the screening plant. The fourth crew member was located in the counting shack operating the counting equipment. A portable air sampler was kept running inside the counting shack during the mining operation.

2.4 DISCUSSION

In order to give a rapid field estimate of the plutonium content of soil, samples were bagged, marked, and taken to the field laboratory where twenty-gram aliquots of blended soil from the CS II and CS III events were spread evenly in the bottom of a cut-off paper cup. The cup was 2 inches in diameter, which is 20 cm^2 in area; therefore, the soil

thickness was 1 gram/cm^2. The vehicle-mounted gamma spectrometer was calibrated using Pu standard #P1347 in the bottom of the cup. To evaluate gamma attenuation by the soil, the source was counted with and without 20 grams of soil cover. Greater than 99% of the Pu gamma was attenuated, but only 27% of the Am gamma was attenuated. Since the Am is mixed throughout the soil instead of at the bottom only, the effective attenuation was probably less than 10% but certainly not more than 15%. For field estimates, this was not considered significant and omitted as a factor in calculation. If we assume that the Am^{241} and Pu^{239} are not fractionated during the detonation, we can estimate Pu content of the soil based on the ratio 10:1, Pu gamma: Am gamma which was observed in a source prepared from parent weapon material. This initial field estimate gave 19.4 grams of plutonium in soil mined on CS II and 21.0 grams of plutonium in soil mined on CS III.

To evaluate some of the parameters that might affect the calibration of the belt monitor, the shield, detector and electronics were returned to the Eberline Instrument Corporation,

Santa Fe, New Mexico, and set up in a trailer to simulate the counting configuration used in the mining operation. Each of the aliquots, representing approximately 10% of the total sample, was counted and compared with the original count of the entire sample. These results, tabulated in Table 2.3, indicate that the aliquot was representative of the total sample for significant counts and, thus, for those samples which contain the majority of the Pu. Each aliquot which was very nearly 10% of the initial sample was also counted closer to the detector. These aliquots were counted as a 2-inch-thick layer of soil, 7 inches in diameter and at a distance of 1.5 inches from the face of the collimator. In this position, the soil subtended the solid angle as viewed by the detector during belt monitor operation. These results, tabulated in Table 2.4, also tend to validate the aliquoting technique to the extent that ± 28% would be the error factor.

The relative efficiency of the belt monitor as a function of source distance from the center of the area on the belt viewed by the detector was checked with an Am^{241} source.

The data are tabulated in Table 2.5 and are presented in graphical form in Figure 2.7. These data were used to calculate a calibration factor for the belt monitor for soil 20 and 24 inches wide on the belt. In both cases the factor was the same as the empirical factor obtained from radiochemistry of the original 20 gram aliquots (see Appendix B).

The effect of depth distribution in the soil was also investigated and a self-absorption factor determined. This was done using ten of the 10% aliquots counted individually in thin layers then collectively in groups from two to ten. The results of this experiment, tabulated in Table 2.6, indicate 23% self-absorption for Am^{241} gamma from soil on the belt.

2.5 RESULTS

The belt monitor data for CS II and CS III are tabulated in Table 2.7 and Table 2.8 respectively. The counting data were converted to grams of plutonium as follows:

grams of Pu = (F) (W) (C)

Where: F = calibration factor based on radiochemistry data and verified by calibration with a standard Am^{241} source.

$$= 0.12 \times 10^{-6} \frac{\mu g\ Pu}{kg\ soil} \times \frac{minutes}{counts}$$

W = weight of soil passing under the detector, kg/min, based on calibration sample weight and belt speed.

C = net Am^{241} gamma counts from the belt monitor

The units cancel out as follows:

$$\frac{\mu g\ Pu}{kg\ soil} \ \frac{minutes}{counts} \ \frac{kg\ soil}{minutes} \ counts = \mu g\ Pu$$

A total of 203 yd^3 of soil containing 23.8 grams of plutonium were mined in CS II and 360 yd^3 of soil containing 24.1 grams of plutonium were mined in CS III. Approximately 80% of the plutonium associated with the soil scavenging was contained within the crater.

The initial field estimate of 19.4 grams for CS II compares favorably with the revised value of 23.8 grams. Likewise the initial field estimate of 21.0 grams for CS III

compares favorably with the revised value of 24.1 grams. This agreement illustrates the value of direct gamma counting as a field evaluation tool.

TABLE 2.1

PLUTONIUM IN SOIL FROM MINING OPERATION

T-Lab No.	EIC No.	Belt Monitor Am^{241} net cpm	Pu^{239} dpm/g	*F
0116	CSII 3	974	58,000 ± 1,200	60
0118	CSII 29	750	41,000 ± 800	55
0120	CSII 13	600	12,000 ± 700	22
0121	CSII 23	7,300	133,000 ± 2,000	18
0122	CSII 6	330	6,100 ± 300	18
0123	CSII 7	2,800	48,000 ± 1,000	17
052	CSII 8	1,070	15,400 ± 700	14
0125	CSII 15	1,790	43,000 ± 2,000	24
0126	CSII 21	3,200	66,000 ± 3,000	21
0127	CSII 26	800	10,000 ± 500	13
0130	CSII 22	5,000	105,000 ±30,000	21
0131	CSII 24	1,800	20,400 ± 1,000	11
0133	CSII 5	340	10,000 ± 300	29
0134	CSII 28	1,000	37,500 ± 1,100	38
0135	CSII 4	360	3,000 ± 90	8
0136	CSII 17	720	19,000 ± 1,000	26
0138	CSII 19	1,140	16,600 ± 400	14
0139	CSII 18	890	19,100 ± 400	21
0141	CSIII 7	153	2,720 ± 10	18
0142	CSIII 13	300	15,600 ± 700	52
0143	CSIII 4	340	9,200 ± 400	27
0144	CSIII 6	840	15,700 ± 700	19
0145	CSIII 11	800	13,600 ± 600	17
0146	CSIII 8	12,230	141,000 ± 4,000	12

*F - factor to convert Am^{241} gamma net cpm to dpm Pu^{239}/g

TABLE 2.2

CALIBRATION OF BELT MONITOR
Based on Am^{241} Gamma Spectrometry

Event	T-Lab No.	Aliquot Weight (kg)	A Belt Monitor Net cpm Am^{241}	B μgPu/kg Soil*	Ratio B/A
CS II	120	1.77	600	206	0.3
	122	1.86	330	429	1.30
	126	1.52	3,200	590	0.18
	130	0.98**	5,000	838	0.17
	131	1.83	1,800	286	0.16
	132	1.81	4,700	818	0.17
	138	1.86	1,140	368	0.32
	139	1.79	890	208	0.23
CS III	140	2.14	2,068	215	0.10
	144	2.04	840	197	0.23

$$\left.\begin{array}{l}\text{Mean ratio } 0.32 \pm 0.35 \\ \text{Median ratio } 0.205\end{array}\right\} \frac{\mu g \text{ Pu per Kg Soil}}{\text{Net CPM Am}^{241}}$$

Mean of net cpm >bkg 0.16 ± 0.03

Median of net cpm>bkg 0.16

* Gamma spectrometry data provided by Hazelton Nuclear Science Corporation.

** This aliquot represented 6% of the total sample instead of 10%.

TABLE 2.3

COMPARISON OF TOTAL SAMPLE AND ALIQUOT COUNTS
USING BELT MONITOR GEOMETRY

T-Lab Sample	Location	A Belt Monitor Total sample Am^{241} net cpm	B Belt Monitor Aliquot Am^{241} net cpm	C Weight, kg Aliquot/total	Comparison (A/B)times (C)
118	CSII, P-29	750	145	1.46/18.5	0.40
120	CSII, P-13	600	155	1.77/17.1	0.40
121	CSII, P-23	7300	867	1.22/11.6	0.88
122	CSII, P- 6	330	307	1.86/11.1	0.17
123	CSII, P- 7	2800	132	1.58/20.1	1.67
124	CSII, P-10	12	11	1.74/17.1	----
125	CSII, P-15	1790	153	2.09/20.4	1.28
126	CSII, P-21	3200	413	1.52/14.8	0.79
127	CSII, P-25	800	153	1.88/18.2	0.54
128	CSII, P-11	0	23	1.94/17.6	----
129	CSII, P-30	20	33	1.38/16.7	----
130	CSII, P-22	5000	505	0.98/16.4	0.59
131	CSII, P-24	1800	272	1.83/17.7	0.68

Table 2.3 (Cont.)

T-Lab Sample	Location	A Belt Monitor Total sample Am^{241} net cpm	B Belt Monitor Aliquot Am^{241} net cpm	C Weight, Kg Aliquot/total	Comparison (A/B)times (C)
132	CSII, P-20	4607	539	1.81/13.6	1.13
133	CSII, P-5	340	50	1.80/19.4	----
134	CSII, P-28	1000	143	1.88/18.4	0.70
135	CSII, P-4	360	32	1.90/18.3	1.16
136	CSII, P-17	720	126	2.12/2.13	0.57
137	CSII, P-27	105	43	1.88/18.2	----
138	CSII, P-19	1140	298	1.86/18.1	0.39
139	CSII, P-18	890	154	1.79/17.9	0.58
142	CSIII, P-13	300	72	1.56/15.0	----
143	CSIII, P-4	340	49	2.08/20.3	----
144	CSIII, P-6	840	160	2.04/19.7	0.54
145	CSIII, P-11	800	101	2.10/20.4	0.82
146	CSIII, P-8	12230	1061	2.21/21.4	1.18
147	CSIII, P-15	620	1034	1.59/15.9	0.06
148	CSIII. P-16	381	597	1.80/17.2	0.06

Table 2.3 (Cont.)

T-Lab Sample	Location	A Belt Monitor Total sample Am^{241} net cpm	B Belt Monitor Aliquot Am^{241} net cpm	C Weight, Kg Aliquot/total	Comparison (A/B)times (C)
150	CSIII, P-3	411	309	2.05/20.0	0.13
152	CSIII, P-5	534	611	1.99/19.3	0.09
153	CSIII, P-14	425	618	1.90/18.3	0.07
154	CSIII, P-17	66	399	1.58/15.1	----
155	CSIII, P-10	807	729	2.30/22.3	0.11

Mean (All data) 0.60 ± 0.45 $(A/B \times C)$

Median (All data) 0.57 $(A/C \times C)$

Mean of net cpm bkg 0.87 ± 0.24

Median of net cpm bkg 0.84

Theoretical factor based on 25% ingrowth of Am^{241} 0.80

*Blanks in this column not calculated because A or B or both values were not statistically significant.

TABLE 2.4

COMPARISON OF COUNTS FROM BELT MONITOR

T-Lab Sample	A Original Count Net cpm (Am^{241})	B Aliquot Count Net cpm (Am^{241})	Ratio A/B
120	600	2,021	0.30
121	7,300	11,487	0.64
125	1,790	1,357	1.32
126	3,200	4,715	0.68
127	800	1,409	0.57
131	1,800	2,295	0.78
134	1,000	1,646	0.61
136	720	1,301	0.55
138	1,140	2,694	0.42
139	890	1,846	0.48
144	840	1,712	0.49
145	800	852	0.94
146	12,230	12,882	0.95
147	620	1,034	0.60
148	381	597	0.64
150	411	309	1.33
152	534	611	0.87

Table 2.4 (Cont.)

T-Lab Sample	A Original Count Net cpm (Am^{241})	B Aliquot Count Net cpm (Am^{241})	Ratio A/B
153	425	618	0.69
155	807	729	1.11

Mean ratio 0.74 ± 0.29

Median ratio 0.64

$$\frac{\text{Original Count Net CPM } (Am^{241})}{\text{Aliquot Count Net CPM } (Am^{241})}$$

Mean of net cpm bkg 0.85 ± 0.28

Median of net cpm bkg 0.95

Theoretical factor based on 25% ingrowth of Am^{241} 0.80

TABLE 2.5

TRAVERSE of BELT MONITOR AREA with Am ^{241} SOURCE
(bkg = 273 cpm)

Distance from	Total cpm					Net Am^{241} cpm*					
Center-Inches	Left	Right	Up	Down	Center	Left	Right	Up	Down	Center	Mean
0					792					519	
2	815	762	751	816		542	489	478	543		513
4	767	788	755	839		494	515	482	566		514
6	692	664	636	750		419	391	363	477		412
8	618	650	555	743		345	377	282	470		368
10	571	466	562	592		298	193	289	319		275
12	465	447	487	476		192	174	214	203		196
14	432	432	439	357		159	159	166	84		142

*The Am^{241} source contained 0.702 μc. To obtain efficiency in cpm/μc, divide the mean by 0.702.

TABLE 2.6

EFFECT OF DEPTH DISTRIBUTI[illegible]

No. of layered samples	Sum of individual cpm (Am^{241})	Observed cpm (Am^{241})	% Absorption
0	0	0	-
1	650	650	-
2	798	792	-
3	1296	1350	-
4	1451	1431	-
5	1857	1754	5
6	2018	1811	10
7	2318	2016	13
8	2541	2098	17
9	2832	2264	20
10	3097	2398	23

TABLE 2.7

CLEAN SLATE II MINING DATA

RUN	COUNTING TIME	LOCATION	SOIL THICKNESS	CUBIC YARDS	BACKGROUND COUNT		TOTAL SOIL COUNT		NET SOIL COUNT		Kg SOIL/MIN.	g OF Pu
					AM^{241}	Pu^{239}	AM^{241}	Pu^{239}	AM^{241}	Pu^{239}		
1	60.00 min	N-E outside	2.25 in	3.88	48,600	16,500	96,143	46,076	47,543	29,576	69	0.39
2	23.75 min	W outside	2.50 in	1.67	19,576	6,789	29,897	11,272	10,321	4,483	77	0.09
3	58.50 min	W outside	2.50 in	4.17	50,368	15,970	106,626	44,434	56,258	28,464	77	0.52
4	57.00 min	W outside	2.25 in	3.69	55,860	22,800	101,615	48,249	45,755	25,449	61	0.33
5	82.00 min	W outside	2.25 in	5.31	85,198	33,046	118,021	47,169	32,823	14,123	65	0.26
6	17.67 min	W outside	2.00 in	4.06	18,182	7,085	20,710	7,957	2,528	872	230	0.07
7	14.75 min	W inside	2.00 in	3.39	26,078	19,735	62,342	23,622	36,264	3,887	270	1.18
8	14.33 min	N-E inside	2.00 in	3.30	14,759	5,388	41,646	13,415	26,887	8,027	200	0.65
9	7.95 min	N-E inside	2.00 in	1.83	5,604	1,566	23,493	8,372	17,889	6,806	230	0.49
10	10.84 min	N-E inside	2.00 in	2.49	8,260	2,916	11,051	5,658	2,791	2,742	230	0.08
11	13.08 min	N inside	2.00 in	3.01	11,379	3,963	15,843	6,831	4,470	2,868	230	0.12
12	21.15 min	N inside	2.00 in	4.86	18,400	6,408	22,936	8,759	4,536	2,351	230	0.12
13	15.60 min	N inside	2.00 in	3.59	18,158	8,439	31,794	12,627	13,636	4,188	230	0.38
14	42.40 min	N-W inside	2.00 in	9.75	62,667	27,390	95,470	38,248	32,803	10,858	220	0.87
15	32.00 min	N-W inside	2.00 in	7.36	48,992	21,792	81,739	29,571	32,749	7,779	270	1.06
16	17.00 min	N-W inside	2.00 in	3.91	18,462	8,874	89,730	25,926	71,268	17,052	280	2.39
17	10.00 min	S outside	2.00 in	2.30	13,120	5,320	22,679	10,213	9,559	4,893	280	0.32
18	26.50 min	S outside	2.00 in	6.09	41,631	18,576	60,103	25,541	18,472	5,965	240	0.53
19	32.00 min	S outside	2.00 in	7.36	38,400	14,208	102,252	48,188	63,852	33,980	240	1.84
20	22.00 min	S-W inside	2.00 in	5.06	53,570	32,164	178,357	78,400	124,787	46,236	180	2.70
21	29.50 min	S-W inside	2.00 in	6.78	68,410	39,677	157,309	82,321	88,899	42,644	200	2.14
22	19.75 min	S inside	1.75 in	3.97	59,269	33,950	68,141	37,662	8,872	3,712	220	0.24
23	19.75 min	S inside	1.75 in	3.97	88,578	47,024	155,776	70,206	67,198	23,182	160	1.30
24	21.30 min	S-E inside	2.00 in	4.90	41,471	22,706	199,813	101,157	158,342	78,451	140	2.66
-	24.50 min	S-E inside	2.00 in	5.64	42,262	16,464	111,904	55,847	69,642	39,383	140	1.17
25	21.90 min	S inside	2.00 in	5.04	37,756	15,680	46,842	24,742	9,086	9,062	150	0.17
26	21.60 min	S inside	2.00 in	4.97	43,632	18,101	49,757	26,378	6,125	8,277	150	0.11
27	19.90 min	S inside	2.00 in	4.58	37,591	15,342	57,687	29,250	20,096	13,908	150	0.36
28	20.00 min	S inside	2.00 in	4.60	36,140	14,340	53,511	27,035	17,371	12,695	150	0.31
29	38.00 min	S inside	2.00 in	8.74	64,486	20,178	89,282	40,943	24,796	20,765	150	0.45
29a	32.00 min	S outside	2.00 in	7.36	48,480	16,768	57,342	21,570	8,862	4,802	150	0.16
30	45.00 min	S-W inside	2.00 in	10.35	69,255	26,055	70,229	28,981	974	2,926	130	0.01
31	18.50 min	N-W inside	2.00 in	4.26	28,471	10,711	27,000	10,000	(1,471)	(711)	130	---*
32	26.90 min	N inside	1.75 in	5.41	28,030	9,307	29,157	10,992	1,127	1,685	130	0.02
33	23.50 min	N inside	1.75 in	4.72	22,395	9,541	26,035	11,758	3,640	2,217	130	0.06
34	32.50 min	N outside	1.00 in	3.74	32,272	14,885	35,813	17,353	3,541	2,468	74	0.03
35	40.00 min	N outside	1.00 in	4.69	38,960	18,760	43,988	22,100	5,028	3,340	74	0.04
36	37.00 min	N-W outside	1.00 in	4.26	38,184	18,130	42,776	21,286	4,582	3,156	74	0.04
37	25.25 min	N-W outside	2.00 in	5.81	22,977	10,529	26,737	12,476	3,760	1,947	150	0.07
38	33.50 min	N outside	2.00 in	7.70	31,021	13,065	33,414	14,783	2,393	1,718	150	0.04
39	33.50 min	N outside	2.00 in	7.70	31,590	13,634	32,708	14,415	1,118	781	150	0.02

TOTAL	23.79
INSIDE OF CRATER	19.04
OUTSIDE OF CRATER	4.75

NOTE: Belt speed 16 ft/min except for Runs 1-5 incl when belt speed was 4 ft/min.

* Power quit during run, all numbers approximate.

TABLE 2.8

CLEAN SLATE III MINING DATA

RUN	COUNTING TIME	LOCATION	SOIL THICKNESS	CUBIC YARDS	BACKGROUND COUNT		TOTAL SOIL COUNT		NET SOIL COUNT		Kg SOIL/MIN.	g OF Pu
					AM^{241}	Pu^{239}	AM^{241}	Pu^{239}	AM^{241}	Pu^{239}		
1	42.00 min	N-E inside	2.25 in	10.88	43,806	18,186	102,118	46,164	58,312	27,978	160	1.12
2	30.30 min	N inside	2.25 in	7.85	32,269	13,271	139,312	66,783	107,043	53,512	160	2.05
3	32.00 min	N inside	2.12 in	7.81	33,120	12,704	83,413	29,063	50,293	16,359	160	0.97
4	48.00 min	N inside	2.25 in	12.43	50,208	19,488	94,482	42,568	44,274	23,080	160	0.85
5	30.00 min	N inside	2.25 in	7.77	35,220	14,580	68,369	33,659	33,149	19,079	160	0.64
6	30.00 min	N inside	2.00 in	6.90	37,230	16,110	42,705	21,765	5,475	5,655	160	0.11
7	37.00 min	N-W inside	2.12 in	9.03	41,884	18,278	107,631	65,558	65,747	47,280	140	1.10
8	37.30 min	N-W inside	2.12 in	9.10	57,927	23,387	121,602	65,472	63,675	52,085	170	1.30
9	15.00 min	N-W inside	2.12 in	3.66	23,046	9,294	19,044	9,217	(4,002)	(77)	170	0.00
10	29.50 min	W inside	2.12 in	7.20	40,798	16,638	50,092	29,527	9,294	12,889	180	0.20
11	14.00 min	W inside	2.12 in	3.42	18,634	7,658	27,629	13,051	8,995	5,393	160	0.17
11a	54.50 min	W inside	2.12 in	13.30	63,383	19,020	152,649	60,647	89,256	41,627	160	1.71
12	49.00 min	S-W inside	2.12 in	11.96	61,397	22,197	71,847	26,515	10,450	4,318	160	0.20
13	47.00 min	S-W inside	2.12 in	11.47	54,473	16,732	311,696	162,817	257,223	146,085	160	4.94
13a	61.50 min	S inside	2.12 in	15.01	69,802	21,771	235,024	95,407	165,222	73,636	160	3.17
13b	34.00 min	S-E inside	1.75 in	6.83	40,052	12,512	63,255	28,562	23,203	16,050	120	0.33
13c	48.00 min	S-E inside	1.75 in	9.65	55,488	17,232	67,982	28,377	12,494	11,145	120	0.18
13d	3.00 min	N-E inside	1.75 in	.60	3,468	1,077	3,060	1,017	(408)	(60)	120	0.00
13e	26.50 min	N-W inside	1.75 in	7.13	31,614	9,805	28,372	10,119	(3,242)	314	120	0.00
13f	4.50 min	S-W inside	1.75 in	.90	5,368	1,665	5,342	2,122	(26)	457	120	0.00
13g	4.00 min	S inside	1.75 in	.80	4,772	1,480	4,063	1,501	(709)	21	120	0.00
13h	19.50 min	S-E inside	1.75 in	3.92	23,263	7,215	52,036	18,189	28,773	10,974	120	0.41
13i	20.00 min	S-E inside	1.75 in	4.02	23,860	7,400	38,992	16,212	15,132	8,812	120	0.22
13j	16.00 min	S-E inside	1.75 in	3.22	19,088	5,920	37,108	16,106	18,020	10,186	120	0.26
13k	36.00 min	S-E inside	1.75 in	7.24	42,948	13,320	56,027	27,899	13,079	14,579	120	0.19
13l	51.00 min	N-E outside	2.00 in	11.73	59,976	25,806	79,047	34,894	19,071	9,088	150	0.34
14	30.00 min	N-E outside	2.00 in	6.90	38,070	14,580	45,127	21,735	7,057	7,155	150	0.13
14a	68.00 min	N-E outside	2.00 in	15.64	79,720	32,840	103,002	49,594	23,282	16,754	150	0.42
14b	116.00 min	N outside	2.00 in	26.68	133,260	54,320	153,169	71,774	20,909	17,454	150	0.37
15	110.00 min	N outside	2.00 in	25.30	121,740	48,100	150,541	71,663	28,801	23,563	130	0.45
15a	48.50 min	N outside	2.00 in	11.15	53,204	20,273	52,735	23,041	(469)	2,768	130	0.00
15b	51.00 min	N outside	2.00 in	11.73	56,865	22,032	64,334	29,266	7,469	7,234	130	0.12
15c	56.50 min	N outside	2.00 in	12.99	59,551	22,543	68,442	28,717	8,891	6,174	130	0.14
15d	52.50 min	N outside	2.00 in	12.27	56,962	20,685	53,598	22,533	(6,364)	1,848	130	0.00
15e	53.00 min	N-W outside	2.00 in	12.19	53,583	18,815	60,796	24,901	7,213	6,086	130	0.11
16	52.50 min	N-W outside	2.00 in	12.27	51,975	18,375	80,524	33,789	28,549	15,414	140	0.48
16a	53.50 min	W outside	2.00 in	12.30	56,335	18,350	83,952	36,163	27,617	17,813	140	0.46
16b	58.50 min	W outside	2.00 in	13.45	61,425	21,645	78,940	32,319	17,515	10,668	140	0.29
17	63.00 min	S-W outside	1.75 in	12.66	69,867	23,562	78,817	31,265	8,950	7,703	120	0.16
17a	2.50 min	S-W outside	1.75 in	.50	2,590	857	2,756	941	166	84	120	0.00
18	67.00 min	S-W outside	1.75 in	13.47	69,345	21,507	71,679	27,537	2,334	6,030	130	0.04
18a	60.00 min	S outside	1.75 in	12.06	62,100	19,260	68,721	27,788	6,621	8,528	130	0.10
18b	55.00 min	S outside	1.75 in	11.05	71,225	25,355	95,529	30,560	24,304	7,205	130	0.38
19	2.00 min	S-E outside	1.75 in	.40	2,590	922	3,702	1,607	1,112	685	130	0.02

NOTE: Belt speed 16 ft/min

TOTAL 24.13
INSIDE OF CRATER 20.12
OUTSIDE OF CRATER 4.01

Figure 2.1 Earth screening plant. (DASA-133-01-TTR-63)

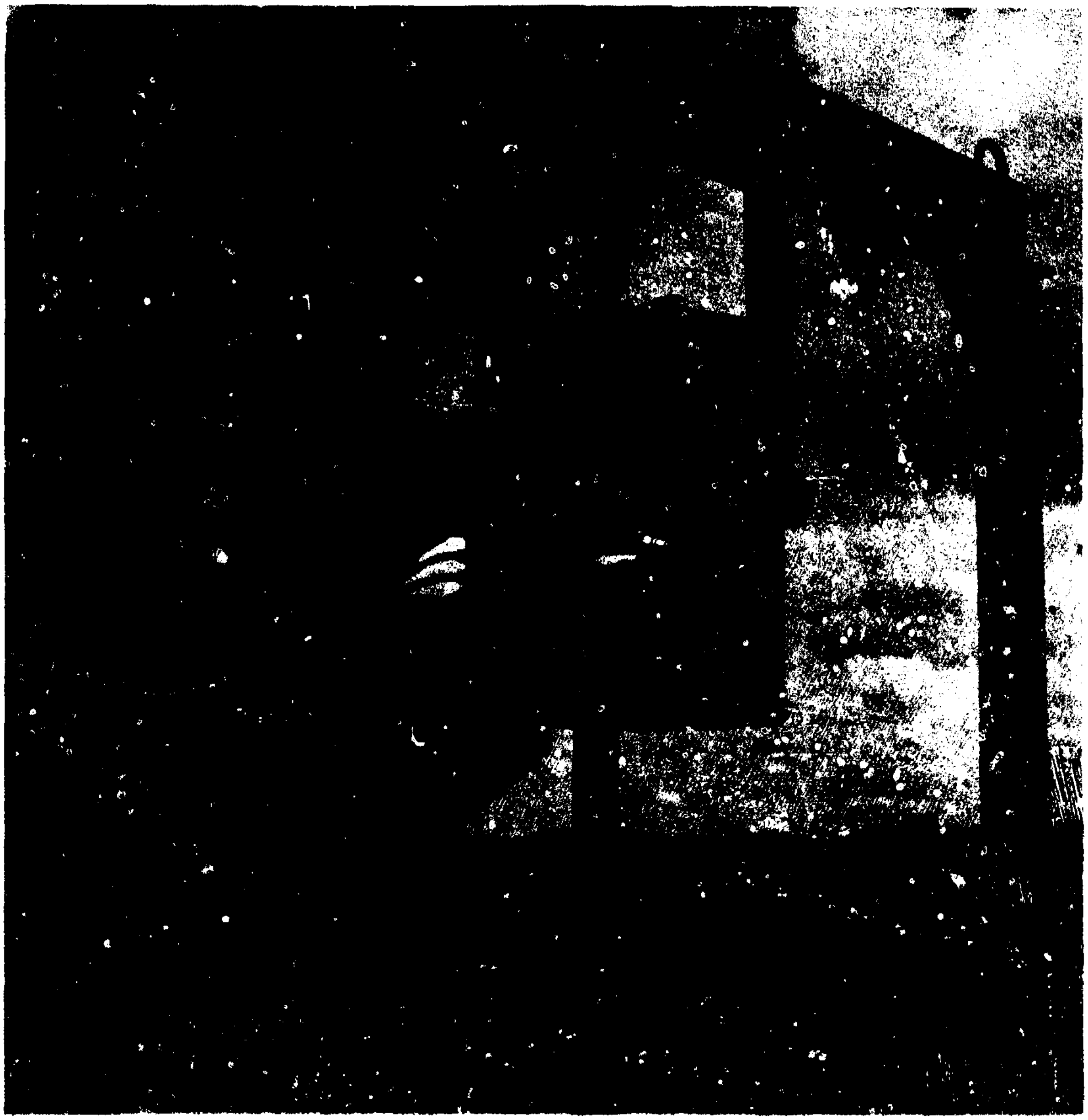


Figure 3.2 Detector unit over belt showing support frame and position relative to soil. (DASA-133-TTR-63)

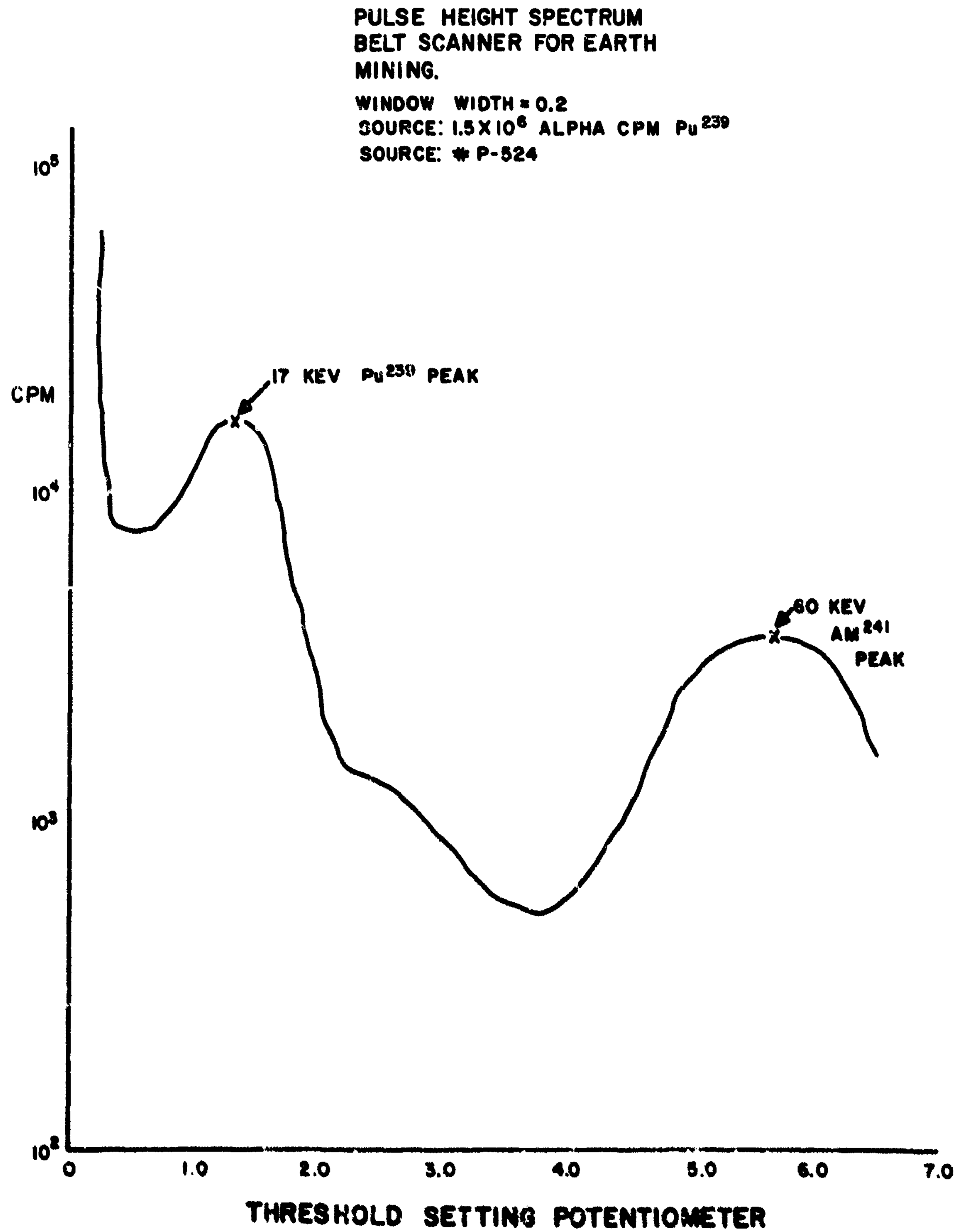


Figure 2.3 Checkout of pulse height spectrum for belt scanner.

Figure 2.4 Earth mining equipment. (DASA-139-31-TTR-63)

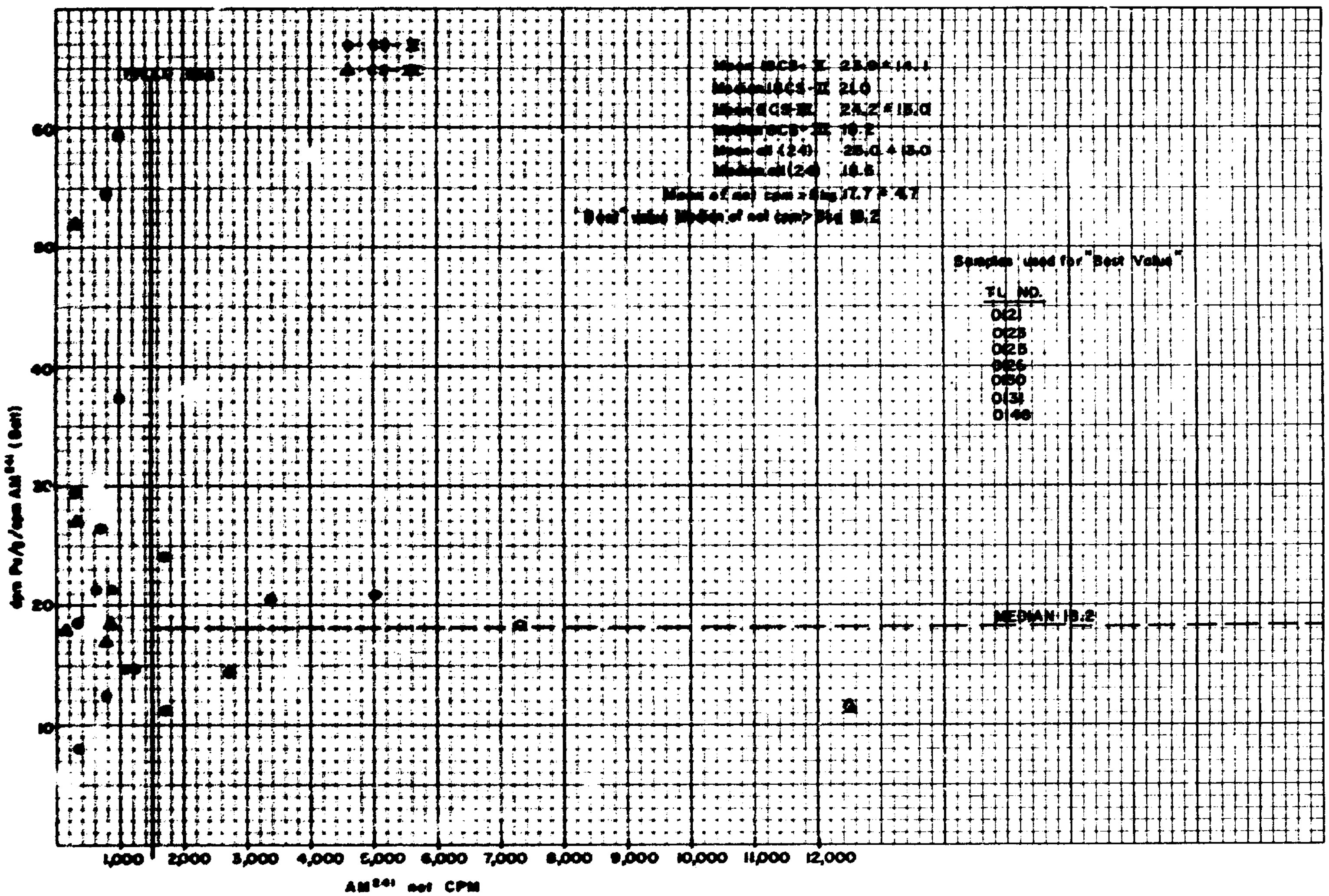


Figure 2.5 Calibration of belt monitor by radiochemistry.

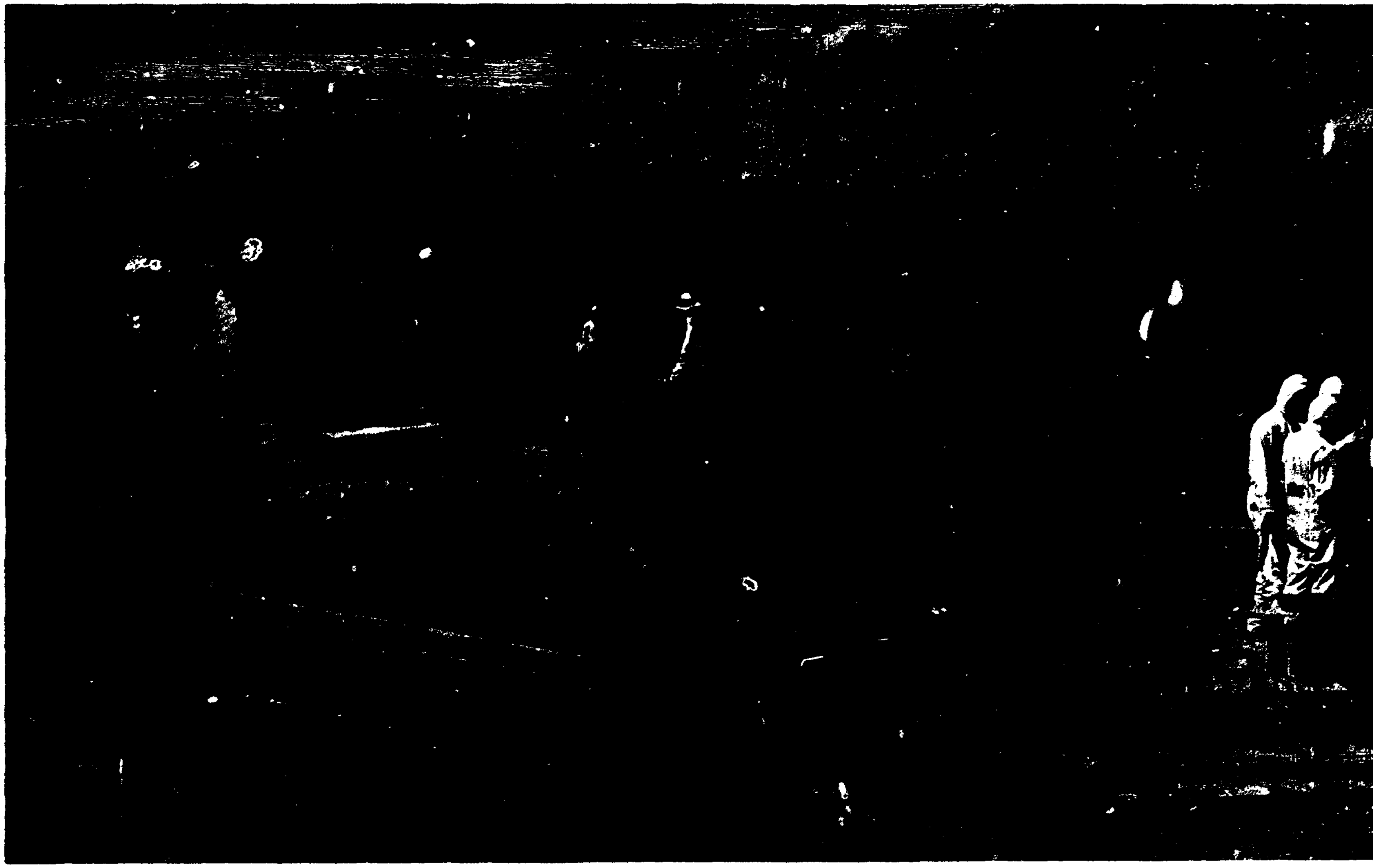


Figure 2.6 Skip loader clearing debris at edge of crater. (DASA-139-13-TTR-63)

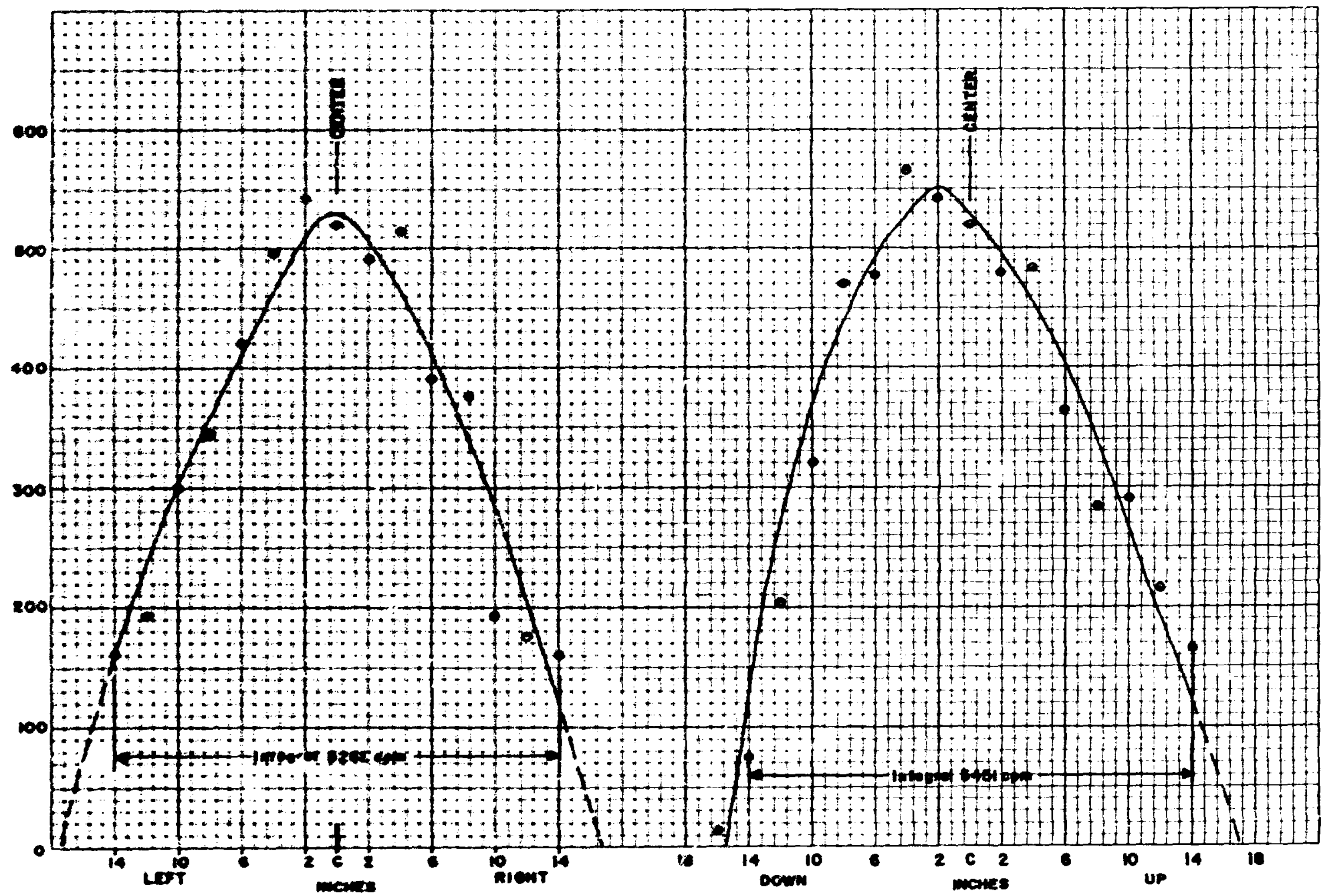


Figure 2.7 Traverse of belt monitor with AM^{241} source.

CHAPTER 3

EARTH CORING

In the conceptual stage of Operation Roller Coaster, little was known concerning the eventual location of the plutonium involved in a detonation inside a storage igloo. It was considered that the major portion trapped by the overburden could be deeply buried, thoroughly mixed, or located predominantly on the surface after the detonation. To settle this question, a requirement was placed in Project 2.1 to investigate the problem. For a solution, it was necessary to design and fabricate suitable coring equipment and core evaluation equipment. Coring equipment was a completely separate design task, while the core scanning system design using the low-energy gamma-detection technique proceeded concurrently with that for the vehicle-mounted gamma scanner and the belt scanner insofar as the detector and electronics were concerned. The mechanical design of the core support and indexing mechanism was also a special design task.

The objectives included in this task were:

1. The design and operation of an earth coring device, scanning equipment, procedures, and accessory devices.

2. The evaluation of soil cores for comparative depth distribution of activity.

3.1 INSTRUMENTATION

Three basic pieces of equipment were required to carry out the earth coring procedures and evaluation for Operation Roller Coaster. These were:

1. A mechanical soil coring device.

2. A detector and electronics system for evaluating soil cores.

3. A mechanical core support and indexing system.

3.1.1 Soil Coring Device and Tools. At first glance, it would seem a relatively simple matter to obtain soil core samples meeting the requirements of Operation Roller Coaster, but further examination of the problem and criteria clearly indicate that this was not the case. The problem was to remove a soil sample contaminated with plutonium in such a manner that stratification of the core and the resultant hole would not be disturbed. The core sample could be a maximum of 4 feet in length and would probably

be taken in dry, loose powdery soil containing a minimum of debris. In addition, the following criteria were established:

1. Require a minimum of effort by personnel using the coring system, because of the adverse condition of working totally enclosed in anti-contamination clothing.
2. All manipulations must be done with heavy gloves.
3. All equipment must work in extremely dusty and high outdoor temperature conditions.
4. Planar orientation of core removed from hole must be maintained.
5. Soil sample must at no time lose its stratification identity.
6. The hole left by removing the sample must be undisturbed.
7. The hole must be large enough so that a radiation instrument may be inserted in the hole.
8. The hole must have a casing with a minimum density of material so that low-energy radiation may pass through (17-kev energy).

9. The core sample removed must have a casing which is of low density material so that low-energy radiation may pass through with minimum loss (17-kev energy).

10. Transportation of the samples must not disturb stratification and identity of material placement in the sample. The outside of these samples must be easily decontaminated so they may be surveyed in a clean area.

11. The equipment must be simple enough to be operated by non-skilled personnel.

12. Sample plugs of the core sample may be taken without damaging the core or contaminating the working area.

13. A method of taking a soil sample must be ready in 30 days for a bunker test.

14. The final production soil coring device must be complete within 60 days.

With these criteria in mind, the following possibilities were reviewed:

1. An auger boring type that would lift the soil

out on the auger.

2. A vacuum cleaning method whereby the soil is sucked out of the hole and redeposited in a tube.

3. Driven mechanisms which would go down inside a tube after it is driven into the soil and clasp the end by either mechanical air pressure or hydraulic means.

4. Standard core drills which rotate as they go down,leaving a core sample.

After exhaustive research and experimentation, it was concluded that the driven method was the only one that seemed to give promise of fulfilling the established criteria.

It appeared that if there were to be a thin core sample retainer, it would be necessary to drive both the casing and sample retainer at the same time. It became obvious that the driven casing must be thin. The inside soil core retainer also had to be thin so that there would be a minimum of soil displacement as the system was being driven to the ground.

Mylar sheet, 0.007 inch thick, was rolled into 2-inch tubes and fastened together with double sticky scotch

tape. This in turn was inserted inside a steel casing. A very thin operating mechanism between the mylar inner liner and the outside casing was developed from flat nylon lacing cord which did not require much space and could be tucked away at the bottom of the tube.

A simple closure design was then developed which had a single flap that could be pulled over to one side to seal the end. Only three manipulating rings were required to pull this flap up and seal properly. Refinements of the core container were made mainly by adding accessory tools such as a cord tension tool and a driver tool. The driver tool was designed to hold the inner core as well as drive the outside casing. A Black and Decker type electric hammer was selected as a driving system, because it was to operate in dusty areas without failure and it had the necessary power to drive the two-inch cylinders into the ground.

After the soil coring method was finalized, it was necessary to develop accessories in order that non-skilled operators could use the system. The following devices were developed as accessories to help the operator:

1. Soil core power driving adapter.

2. String tension and withdrawal tool.

3. A sample hold transfer casing tool.

4. A portable scaffolding system.

5. Core sample holding and handling boxes.

6. A soil sample sealing method.

Upon completion of the initial equipment, an opportunity to field test the system was available at China Lake Naval Ordnance Test Station in California. This was a bunker shot and all equipment was ready and in place in time for the shot. However, through a misunderstanding of construction criteria at China Lake, the bunker was inadvertently compacted and did not provide a suitable medium for testing the coring equipment. Soil cores were taken under field conditions, but their quality was poor; the exercise did, however, provide a limited test that resulted in some design improvements.

The captions and photos of Figures 3.1-a through 3.1-l more fully describe in detail the operational procedures used in the field.

3.1.2 Detector and Electronics for Soil Core Scanning. The detector design for the core scanner was started concurrently with the detectors for the belt scanner and the vehicle-mounted gamma scanners. Design of all detectors was made the same for ease of field service and design simplicity. The photomultiplier tube was a 3-inch-diameter DuMont 6363. The detector was a 2 1/2-inch-diameter by 1-inch-thick NaI (Tl) crystal, Harshaw type HS, with a 0.001-inch-thick aluminum window. The phototube was shielded by 2 inches of lead and housed in an 11-inch-diameter steel pipe. Provisions were made for a compartment inside the detector for dry ice to cool the phototube if necessary. The lower section of the detector was removable. A hole was placed in this lower section so that the core sample could be passed through normal to the photomultiplier tube. In this manner, the phototube scanned a section of the core sample which measured 2 inches in diameter. In order to scan the entire core in any one position, the core was rotated to each of four quadrants.

The counting electronics for core scanning consisted of the following:

(1) Preamplifier, RIDL Model 31-20

(1) Amplifier, RIDL Model 30-20

(2) Pulse Height Analyzer, RIDL Model 33-10

(1) H.V. Power Supply, RIDL Model 40-9

(2) Scaler, RIDL Model 49-28

(1) Timer, RIDL Model 70-10

(2) Cabinet, RIDL Model 29-1

The preamplifier was mounted on the outside of the detector. All other equipment was housed in a standard Emcor cabinet except the timer. The timer was used as a separate piece of equipment and could be placed at any convenient location near the counting electronics.

Preliminary checkout of all equipment took place at the Eberline Instrument Corporation in Santa Fe, New Mexico. A pulse height spectrum was run, and a curve of this spectrum is shown as Figure 3.2. Settings for the counting electronics were as follows:

H.V. setting, 840 volts
Window width, 0.2
Operational mode, differential
Coarse amp gain, 1/8
Fine amp gain, 0.05
Source used for spectrum, Pu^{239}
EIC source 4P524, 1.5×10^6 cpm alpha 2π

Final threshold and window settings were made at the following points:

Channel 1 (Am^{241})	Channel 2 (Pu^{239})
Threshold, 60.0 Kev	Threshold, 10.0 Kev
Window, 20.0 Kev	Window, 20.0 Kev

3.1.3 Core support and Indexing Mechanism. In order to insure accurate and consistent positioning of soil cores for scanning, a special support and indexing mechanism was designed and produced. This portion of the core-scanning system consisted of a track which was in two pieces. One section of the track was mounted at each side of the detector. This track had rollers to guide the core sample into the detector. One of the tracks contained a movable indexing head which slid along the track to indicate core position. A scale was engraved on the track to aid in positioning.

3.2 CALIBRATION

The soil coring equipment required no calibration. Core scanning equipment did not require actual calibration, since this was only a qualitative investigation; but proper operation was checked by the use of a standard plutonium source and a background check prior to scanning operations.

3.3 PROCEDURES AND OPERATIONS

Core-scanning equipment was first set up in a small shack 3,000 feet north of ground zero, Clean Slate II. After the Clean Slate II event, the entire shack was moved to approximately 400 feet north of ground zero. Forty-one soil cores were taken on D+1 from the inner and outer walls of the crater, as well as on the lip as shown in Figure 3.3. After wiping the surface of the core samples with a damp Kemwipe and monitoring the outside surface of the cores with a PAC-3G, it was determined that the surface was free of contamination. Due to the inconvenience of counting the cores in full anti-contamination clothing and since the core tubes were not contaminated, the equipment was moved into Base Camp and set up in a trailer where the counting operations were performed (Figure 3.4).

Forty-five soil cores were taken after the CS III event on D+1 and D+2 at locations shown in Figure 3.5. The soil-coring operations were carried out very successfully by crews using basically the same procedure as previously described, while dressed in full anti-contamination clothing (Figures 3.6-a, b, c, d, and e).

The cores for Clean Slate II and III were counted in each quadrant at 2-inch intervals along the length of the core. In general it was found that all of the contaminated soil was to be found in the first 3 inches below the surface of the ground. This information proved to be valuable in the mining operation which followed.

3.4 DISCUSSION

The soil-coring operations proved to be very successful in obtaining core samples. The gamma scanning technique was an excellent method for qualitative determination of the vertical distribution of the plutonium. Initial core scanning data were useful as a guide to carrying out mining procedures. Preliminary scanning was carried out for all soil core samples at the trailer in Base Camp at the Tonopah Test Range; but since project personnel had some doubt as to the accuracy of all data, soil cores were returned to Eberline Instrument Corporation in Santa Fe, where they were again counted.

After counting procedures were complete, certain cores were selected for radiochemical analysis for comparison

to gamma counting. In some cases, 20-gram aliquots of a 1-inch section of the core were analyzed by radiochemistry, and in other cases, the entire core sample was analyzed in 1-inch sections.

3.5 RESULTS

The gamma scanning data for soil cores is presented in Appendix A. Evaluation of this data indicated that most of the plutonium was contained in the upper 3 inches of the soil core, with a few exceptions. These exceptions generally occurred within the crater or at a location where earth slippage subsequent to the detonation was considered to be the most probable cause of the increased depth of burial.

Quantitation of gamma scanning data through radiochemistry was performed on selected cores. The depth distribution curve could be validated (Figure 3.7) by this method so long as each incremental sample was analyzed in toto. Such was not the case if only an aliquot of the sample was analyzed.

Remove red plastic protector caps from each end of loaded coring tube assembly. Inspect to see that tube tip bushing is in proper place with fingers pointing in and covering closing strings.

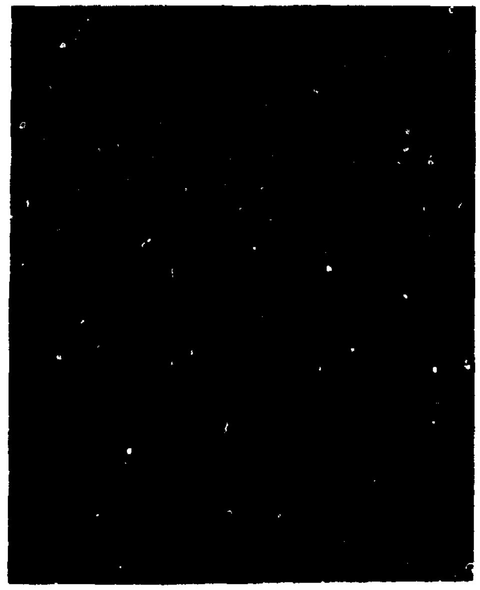
Push core tube assembly vertically into soil by hand as far as possible. Push on outer tube only.

Figure 3.1a Soil coring procedures. (Eberline Instrument photos)

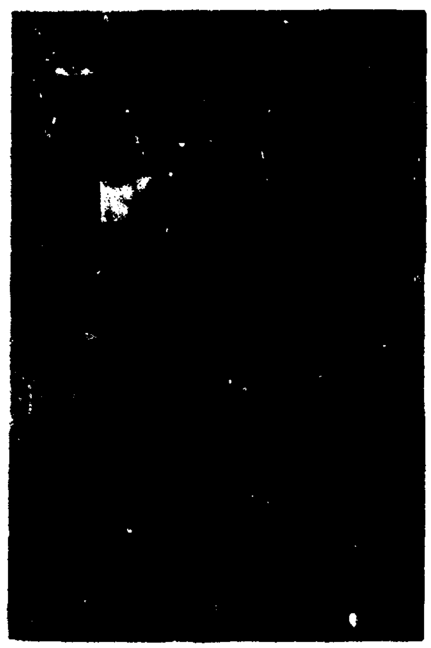
Fold closing string and insert through driving tool string exit hole. Be sure strings are pulled together so they are the same width as the exit hole. This prevents strings being cut between driving tool shoulder and external core tube.

After carefully seating the driving tool over core tube, proceed to use electric hammer to complete the driving of core tube into soil. Watch closing strings to avoid cutting them at the driving tool string exit hole.

Figure 3.1b Soil coring procedures (continued). (Eberline Instrument photos)



Remove driving tool. Inspect sample depth in coring tube. If more than one-third of the sample has settled or displaced, a new core should be taken. Place external tube hold over the assembly as shown.



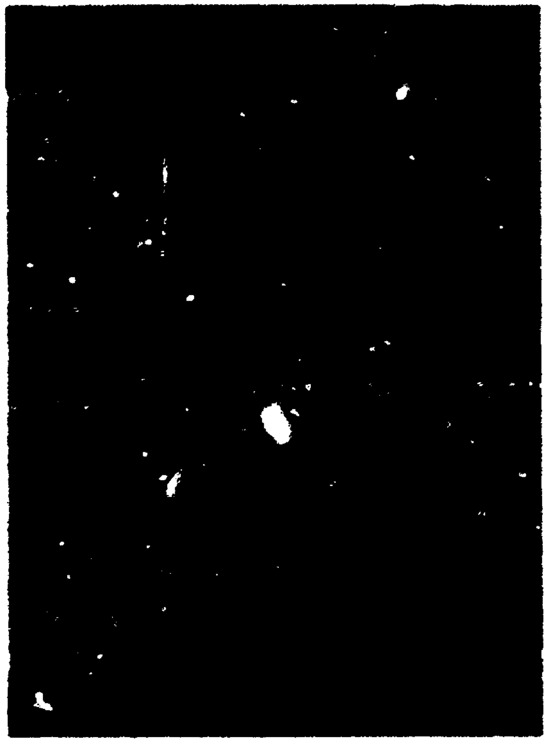
Place closing cord tension tool in inner core tube and draw tension only on the two outer strings. Avoid excessive tension which will break strings.

Figure 3.1c Soil coring procedures (continued). (Eberline Instrument photos)

Remove two outer closing strings from tension tool and pull tension on middle string only. At this time the inner core tube retainer flap should be partially closed.

Remove string tension tool. Mix polyurethane in can for 30 seconds only while stirring vigorously, immediately pour into coring tube. Allow to set for 20 minutes.

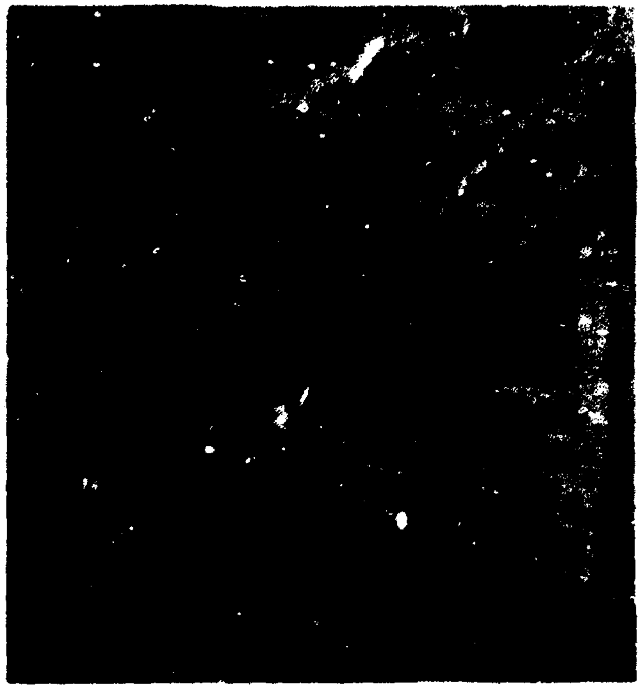
Figure 3.1d Soil coring procedures (continued). (Eberline Instrument photos)



Place string tension tool in inner coring tube and pull tension on all three sets of strings at once. Put downward pressure on tension tool to force inner core tube hold-down tool and pull on close soil retainer flap. Withdraw inner core by placing feet on external core tube hold-down tool and pull on both string tension tool and inner coring tube.

Closed inner core tube soil retainer flap as withdrawn from hole.

Figure 3.1e Soil coring procedures (continued). (Eberline Instrument photos)



Invert the inner core tube and place in handling box. Remove strings. Use wood doweling to tamp soil in tube. Use care to avoid stratification of soil by uneven tamping. About two inches of tamping is sufficient.

Place paper funnel around flap end of inner core tube and hold in place with masking tape. Mix polyurethane for 30 seconds while stirring vigorously. Immediately pour into coring tube. Allow to set for 20 minutes. Dispose of empty containers and waste in hollow section of tube-handling boxes.

Figure 3.1f Soil coring procedures (continued). (Eberline Instrument photos)

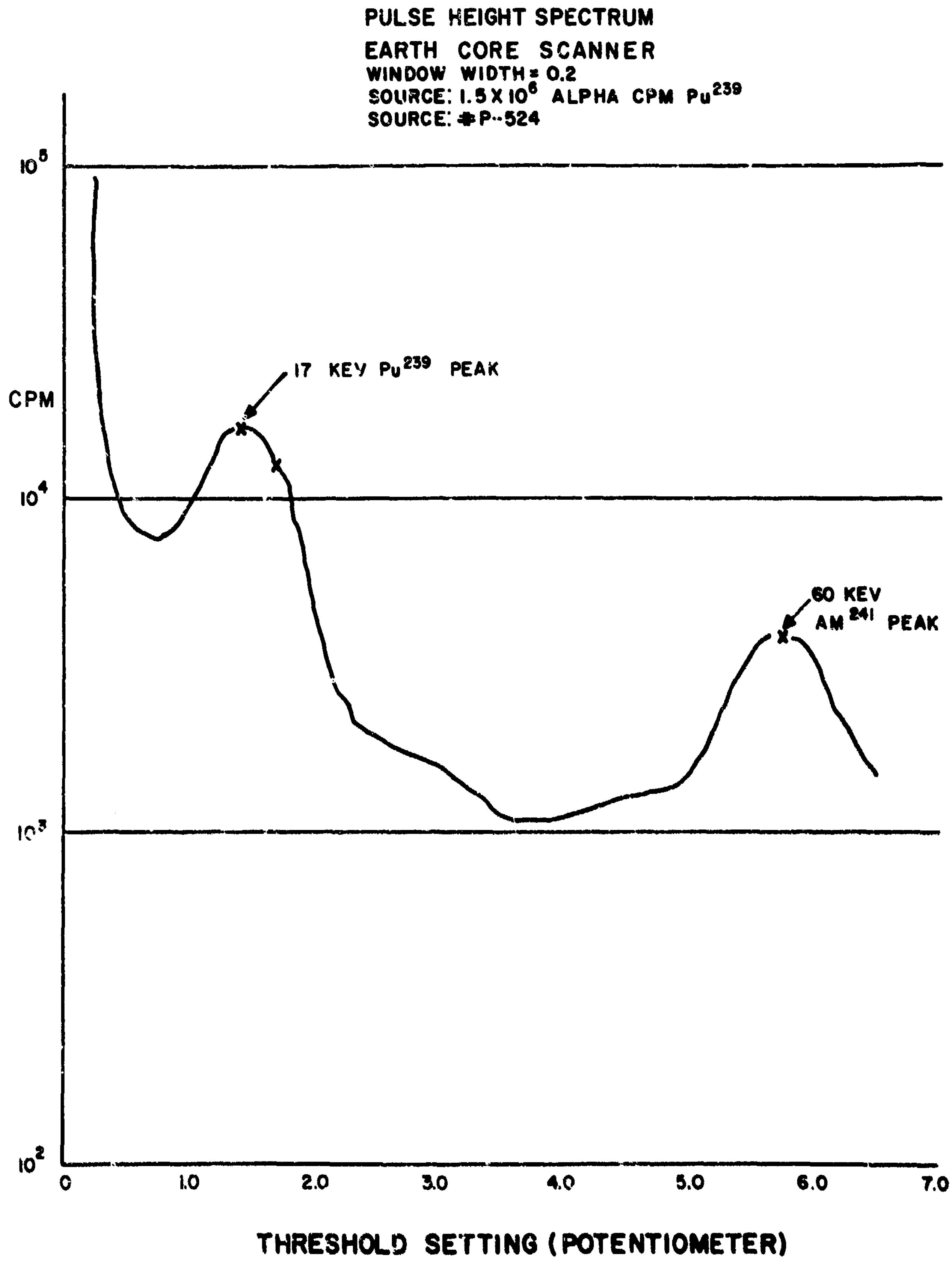


Figure 3.2 Checkout of pulse height spectrum for core scanner.

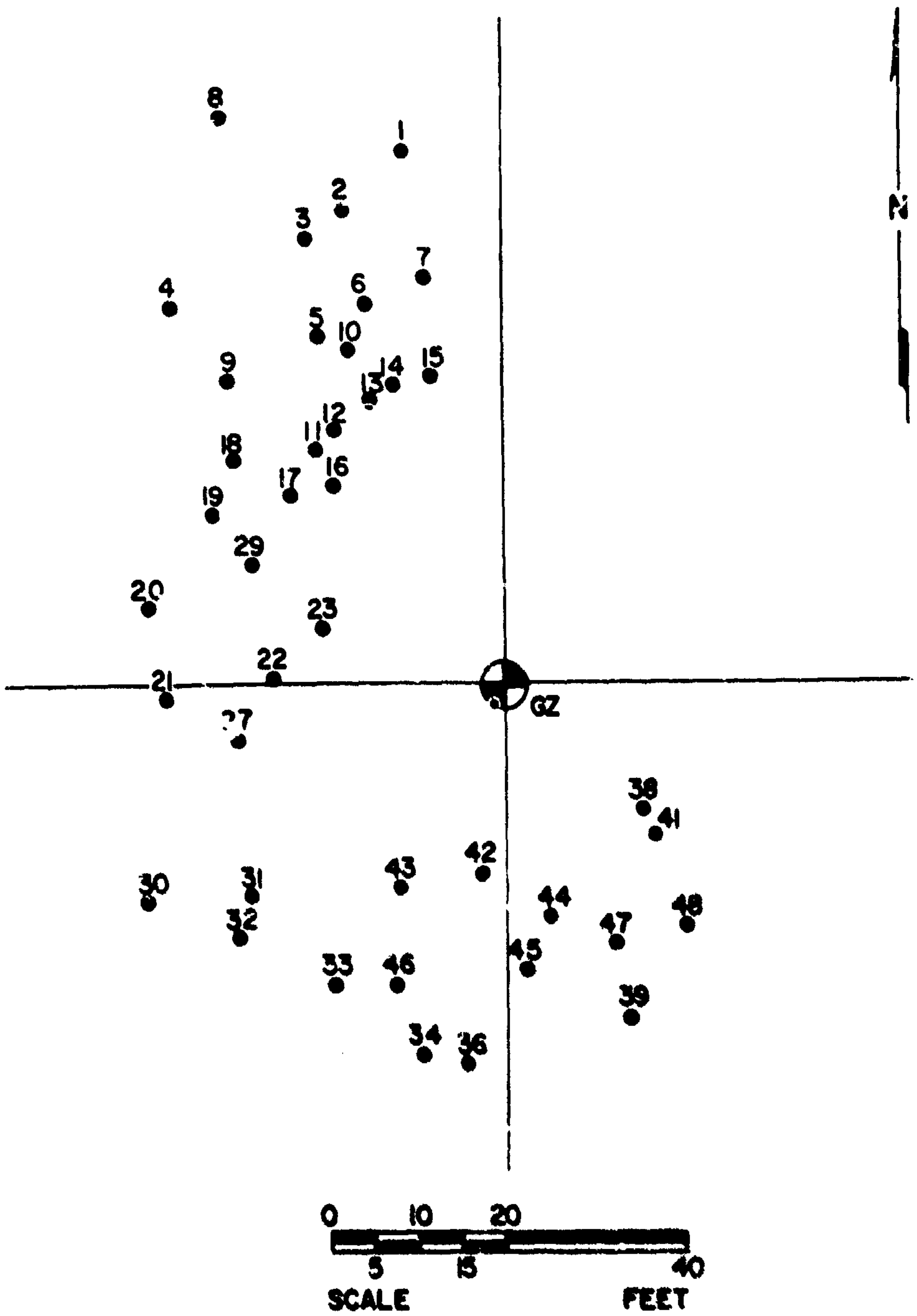


Figure 3.3 Location of earth core samples, CS II.

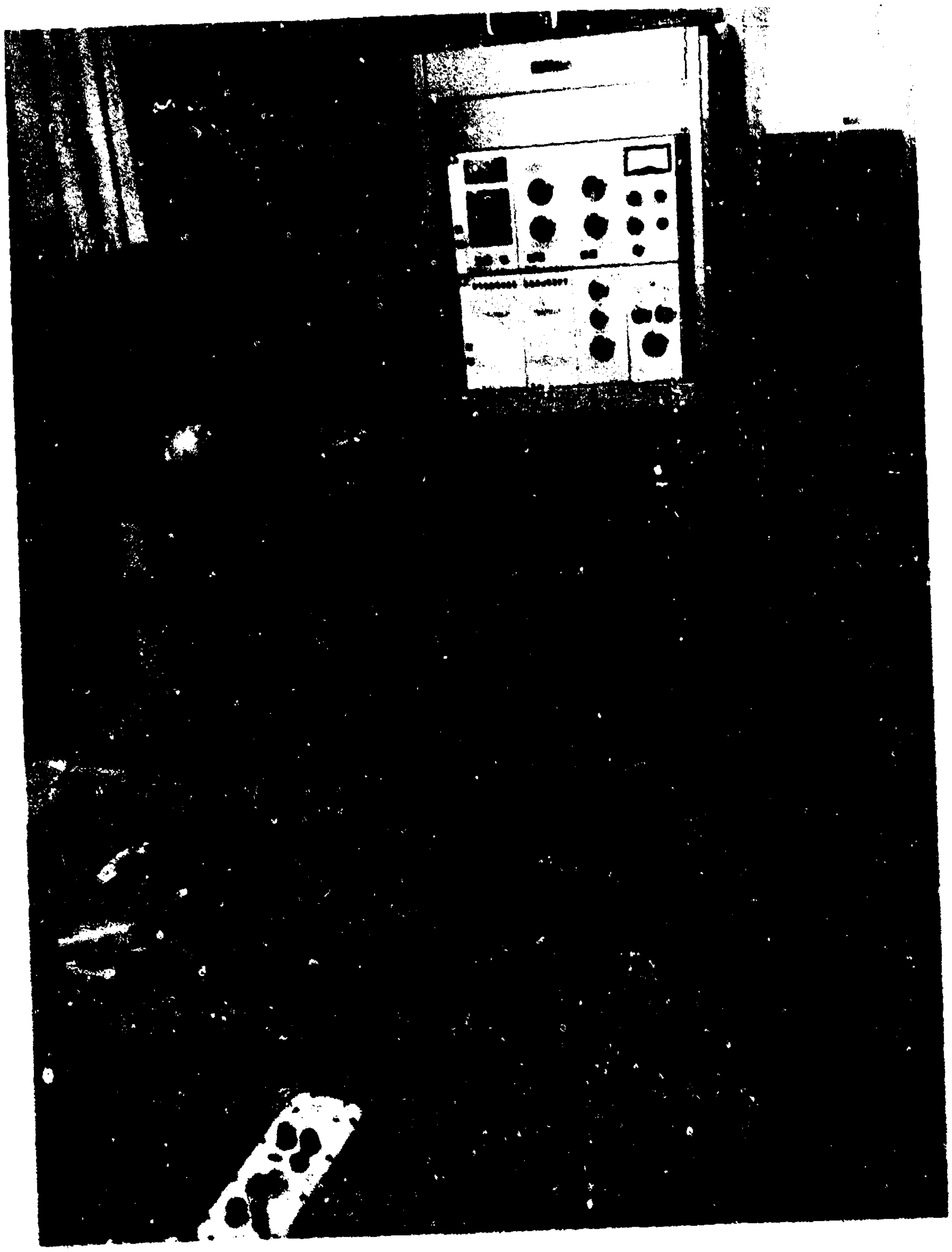


Figure 3.4 Core scanning equipment, Tonopah Test Range. (DASA-130-11-TTR-63)

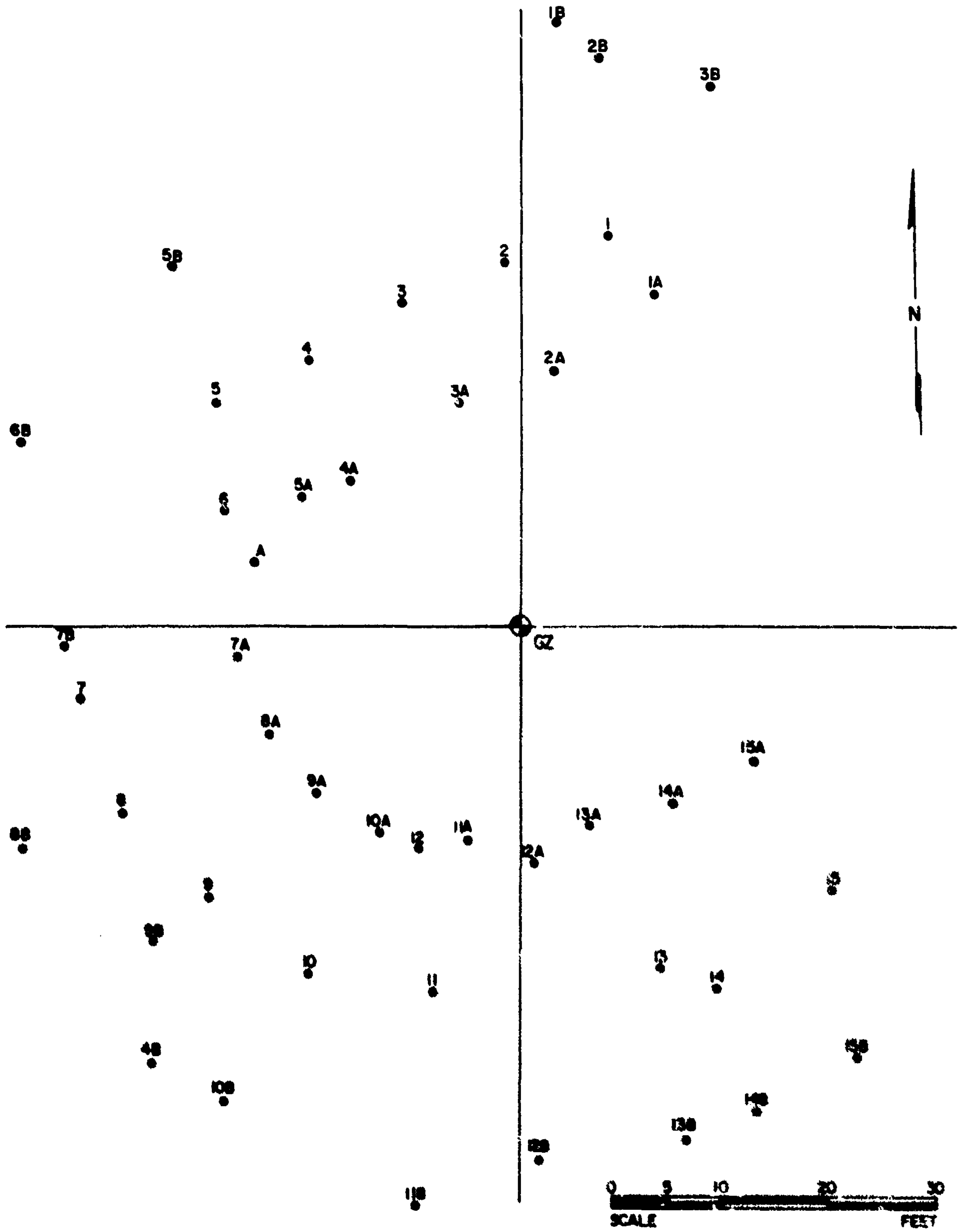


Figure 3.5 Location of earth core samples, CS III.

Figure 3.6a Core-sampling team operations. (DASA-128-09-TTR-63)

Figure 3.6b Core-sampling team operations (continued). (DASA-128-12-TTR-63)

Figure 3.6c Core-sampling team operations (continued). (DASA-128-13-TTR-63)

Figure 3.6d Core-sampling team operations (continued). (DASA-139-12-TTR-63)

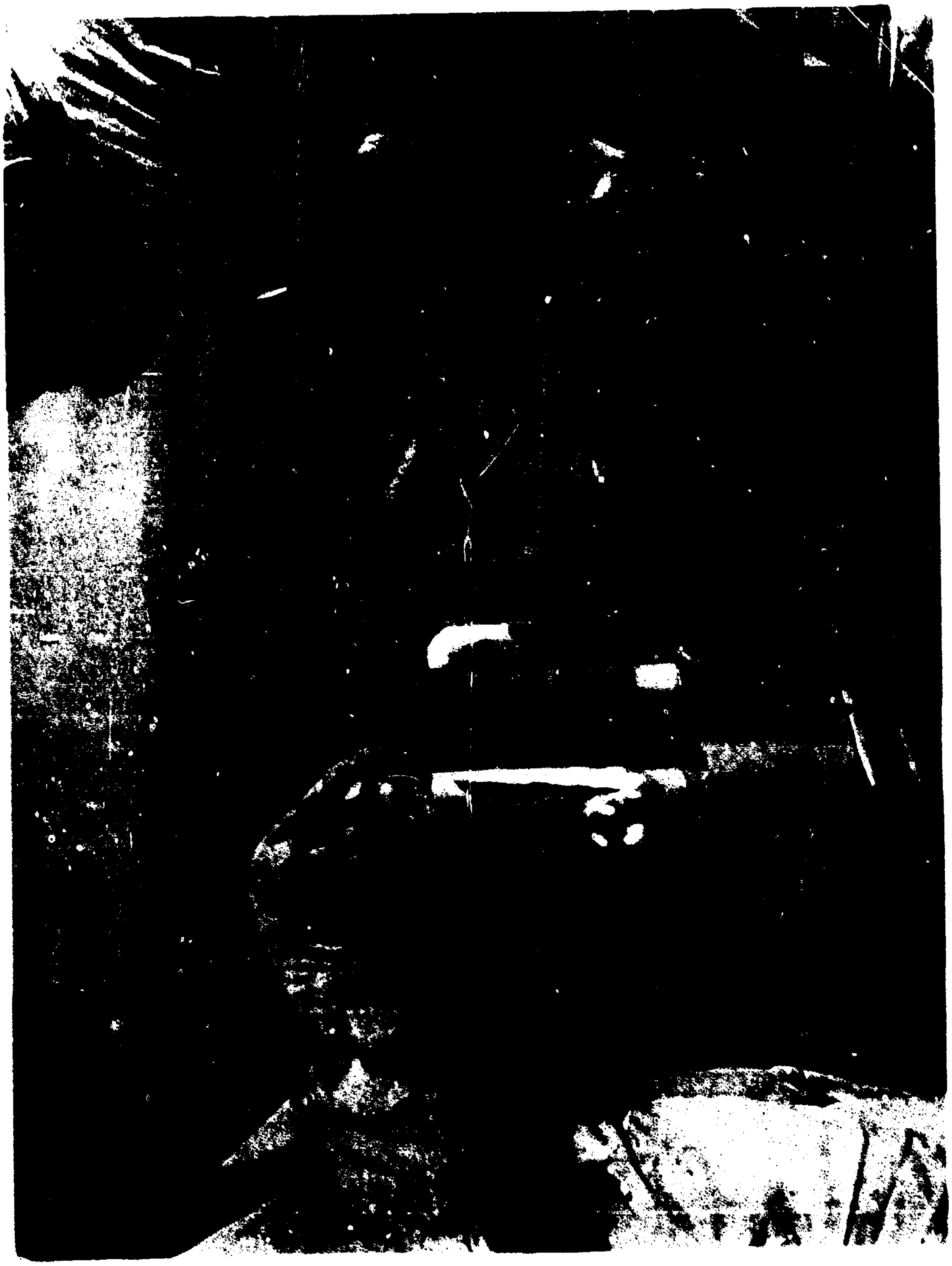


Figure 3.6e Core-sampling team operations (continued). (DASA-139-28-TTR-63)

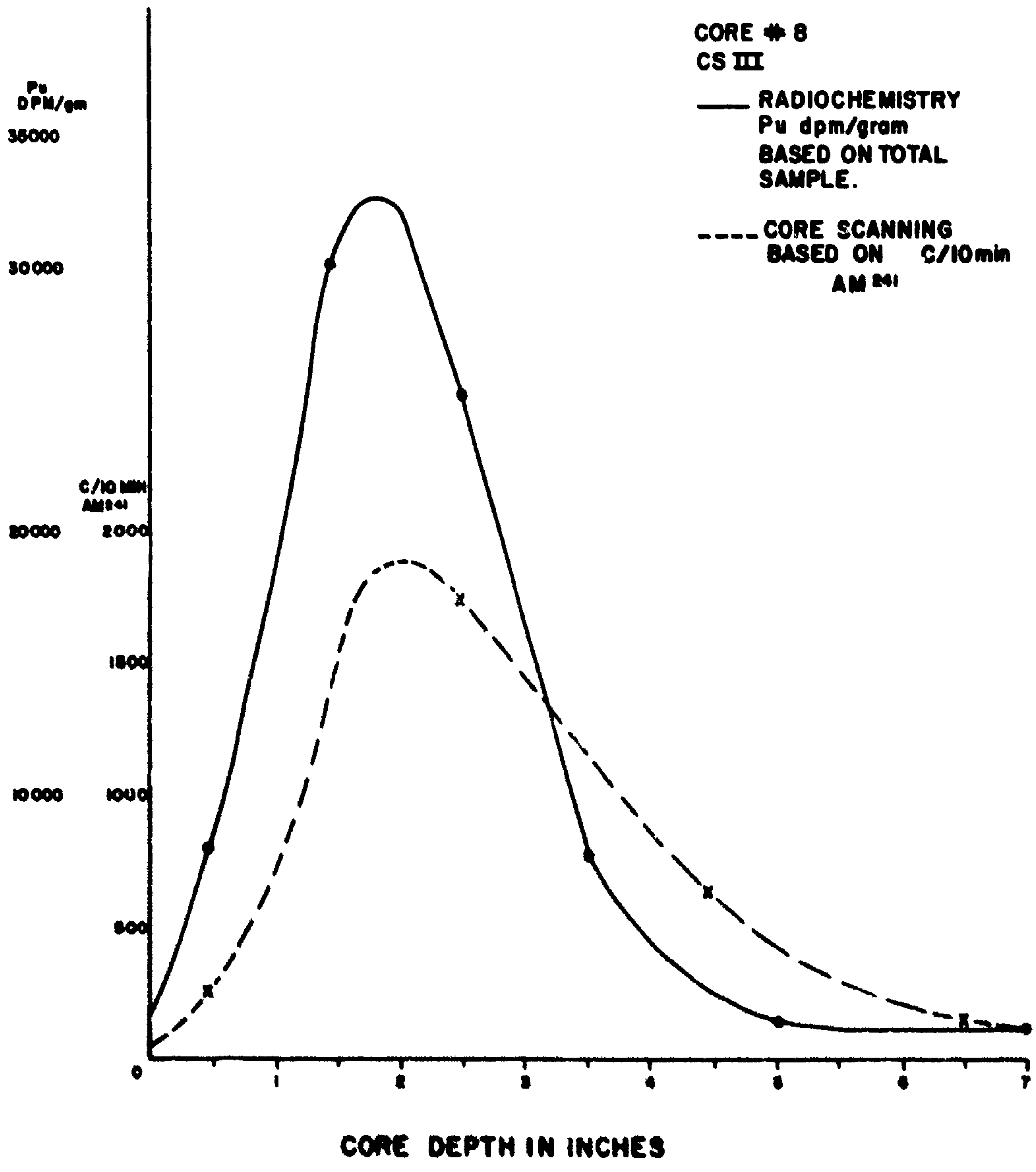


Figure 3.7 Core depth distribution data.

CHAPTER 4

EARTH THROW-OUT

In order to evaluate mixing and total plutonium content of the overburden soil from Clean Slate II and III, it was desirable that soil samples be collected which were separated from the surrounding soil and consisted only of overburden material. Also, such samples would reduce the total volume per sample which had to be analyzed. Initially, it was considered that special trays would be fabricated. Experience at Sideshow proved the efficacy of plastic-lined galvanized tubs and pie pans. These were selected in the interest of increasing the density of collectors without increasing the cost over that of a few special trays. The group implementing the earth throw-out portion of Project 2.1 participated only in Clean Slate II and III, as a sample collection team in support of Project 2.6, Special Particulate Studies.

4.1 INSTRUMENTATION

Instrumentation for this work was very simple and inexpensive. Calculations were made as to throw-out distances, and five-gallon wash tubs lined with plastic bags

were used as collectors within 300 feet of ground zero (Figure 4.1). The tubs were buried so that only about 2 inches of the top protruded above the surface. This procedure minimized blast fragmentation and missile damage and reduced the possibility of resuspension contamination. At greater distances, 8-inch aluminum pie pans were used and held in place by a spike which was then taped over. Instrumentation arrays were similar for CS II and CS III and are shown in Figures 4.2 and 4.3.

4.2 PROCEDURES AND OPERATION

Instrumentation was placed on the arrays at D-1. After each event, a visual inspection was made of each station by 2.1 personnel, and tubs which contained a significant sample had the plastic bags removed and the contents placed in polyethylene bottles. Personnel of the special recovery team removed the samples and returned them to the sample processing and control center.

4.3 DISCUSSION

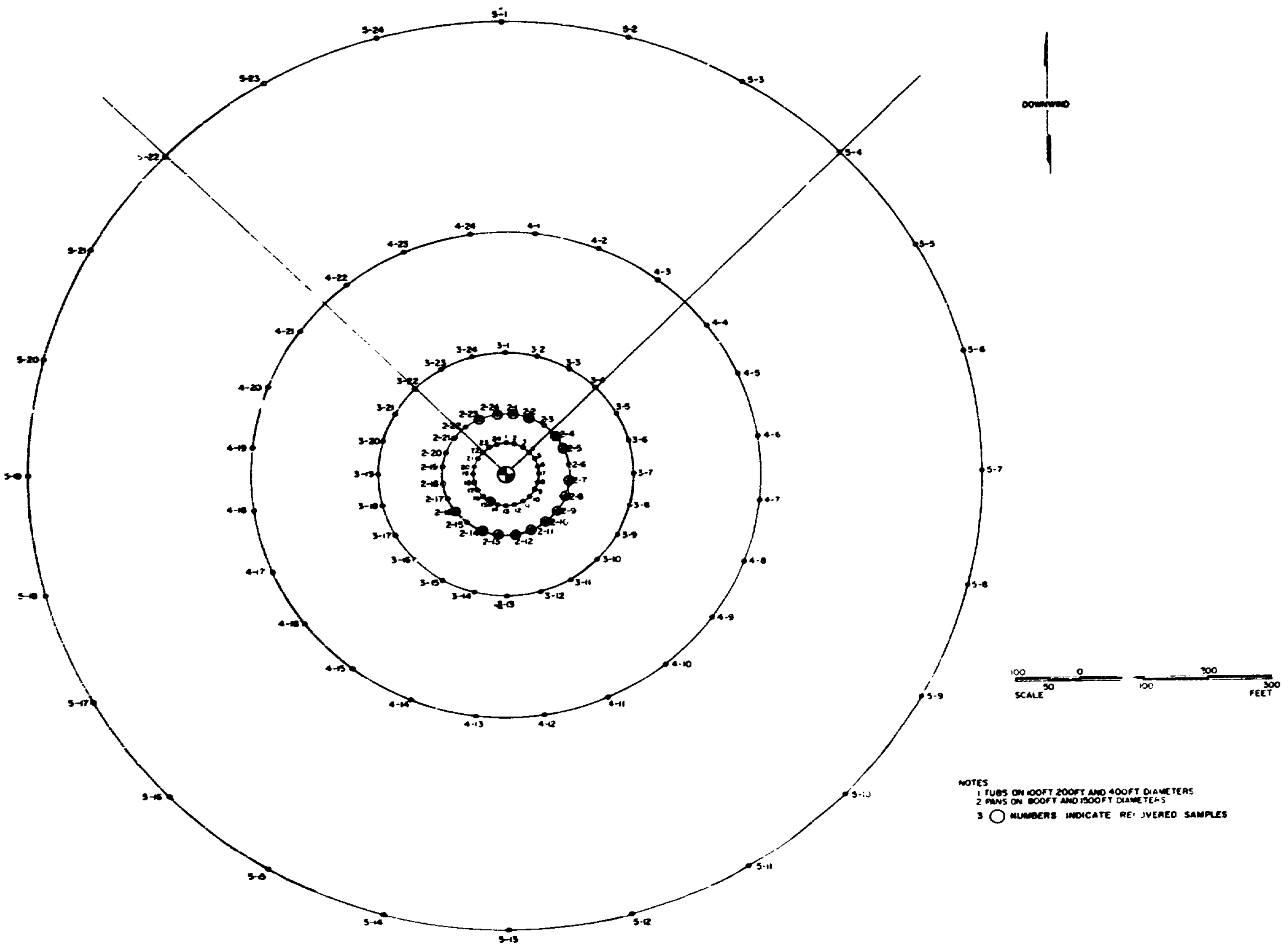
The use of tubs and pie pans as a collection device for undiluted igloo soil samples was basically successful, but many difficulties were encountered, not so much with

procedures, as with unintentional destruction and perturbations of the array layout. With collectors being placed at D-1, vehicular traffic in the array areas destroyed some of the stations. Seventeen samples were collected from CS II and twelve samples were collected from CS III. The size of these samples varied from a few ounces to several pounds. The samples were turned in to the sample control center for further distribution and processing.

4.4 RESULTS

In all, 29 samples were collected from the two events, from locations shown in Figures 4.2 and 4.3. The area of tub collectors encompassed the area where throw-out was a factor. The pie pan array was essentially superfluous.

Figure 4.1 Plastic-lined collector in throw-out area. (DASA-128-02-TTR-63)



FALLOUT CATCHER ARRAY FOR CLEAN SLATE II

Figure 4.2 Throw-out sampling array, CS II.

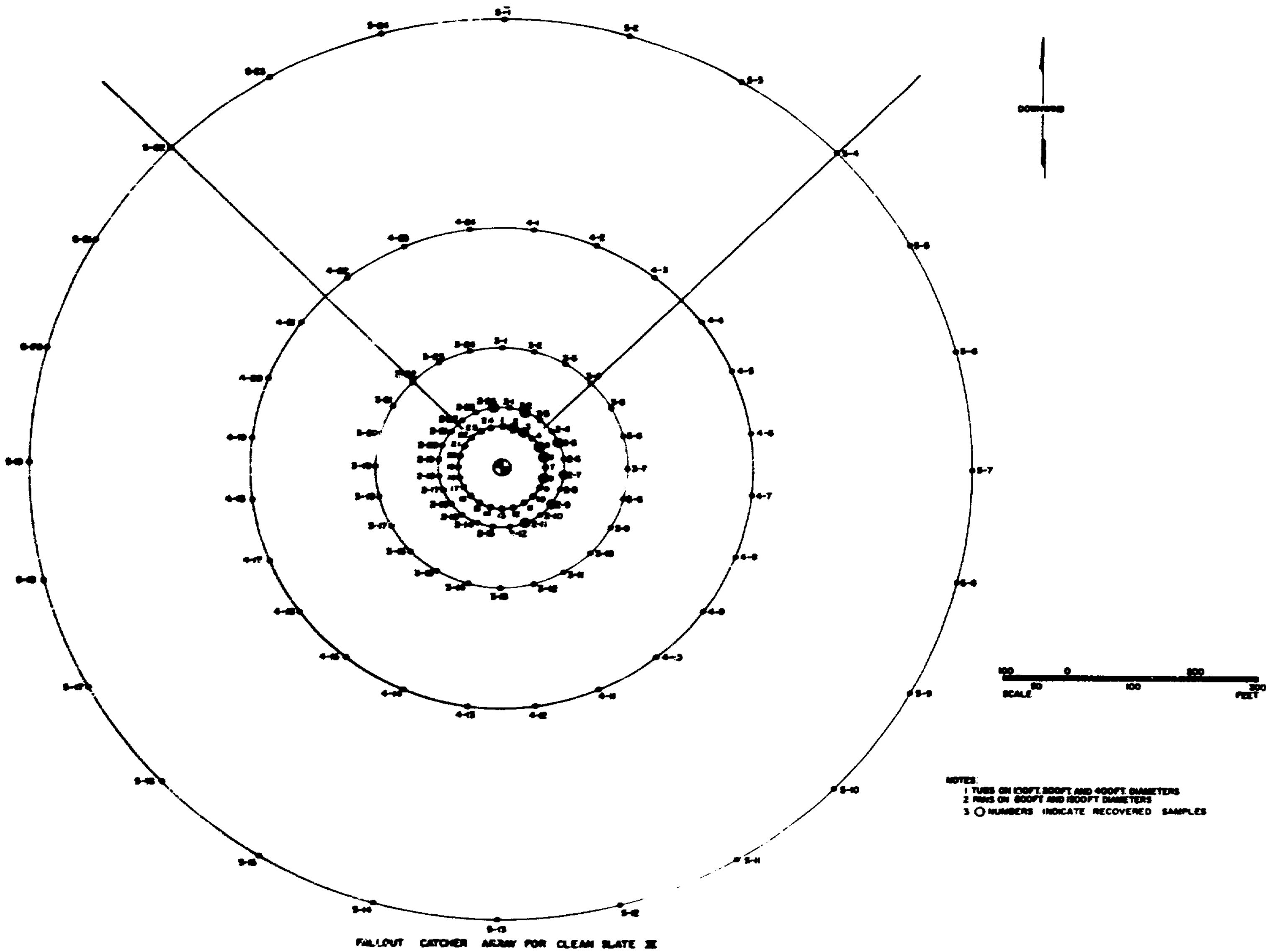


Figure 4.3 Throw-out sampling array, CS III.

CHAPTER 5

CONCRETE CORING

5.1 INSTRUMENTATION

In order to insure that every potential scavenging effect was investigated and that accountability data would include all sources of deposition, it was necessary to devise a method to evaluate concrete GZ pads for plutonium content. It was originally anticipated that this would be accomplished by removal of the concrete cylinder $1\frac{1}{2}$ inches long by 2 inches in diameter. Considering the personnel and equipment requirements necessary to obtain such a core sample, and the fact that it might have to be obtained under very adverse conditions, other methods for collecting the same data were investigated. Final evaluation of these methods resulted in a special design basically incorporating a star drill and an electric power hammer coupled with special techniques and procedures and employing a somewhat different philosophy as to the character of the sample obtained. Instead of taking a solid core for examination, the star drill would powder the concrete to the desired depth, leaving a hole that could be

measured for depth of penetration if necessary. The resultant powdered concrete could be more easily examined by radiochemistry and gross counting for plutonium content. The major problems anticipated with this procedure were prevention of cross-contamination, operation in a windy situation, and pick-up of concrete dust. The following pictures and list of equipment and procedures will illustrate how these problems were solved.

Equipment required:

1. Black and Decker electric hammer, #104, 115VAC.
2. A rotating electric hammer handle, Black and Decker #21726.
3. Two-inch electric hammer star drill 18 inches long.
4. Dry stick.
5. Rubber plunger dust shield.
6. Small size polyethylene wide-mouth bottles.
7. Twelve-inch square mylar mask with a 2-inch hole in the center.
8. A 2-inch metal disc to act as a dry stick mask.
9. Pick-up spatulas and spoons.

Procedures:

The procedure for obtaining a concrete core sample is described and illustrated in Figures 5.1-a, b, and c.

5.2 CALIBRATION

The concrete coring device was purely mechanical and required no calibration. Calibration procedures have been previously described for the electronic equipment and detectors which were used to evaluate the concrete core samples.

5.3 PROCEDURES AND OPERATIONS

The established and tested procedures and equipment were used on all four events of Operation Roller Coaster under field conditions and operated very effectively in all cases. The samples obtained were sealed in wide-mouth polyethylene bottles, marked for identification, and forwarded to the sample control center for further processing and distribution.

5.4 DISCUSSION AND RESULTS

Since the basic task of this group was to obtain suitable concrete core samples from certain events of Operation Roller Coaster, it can be stated that this task was

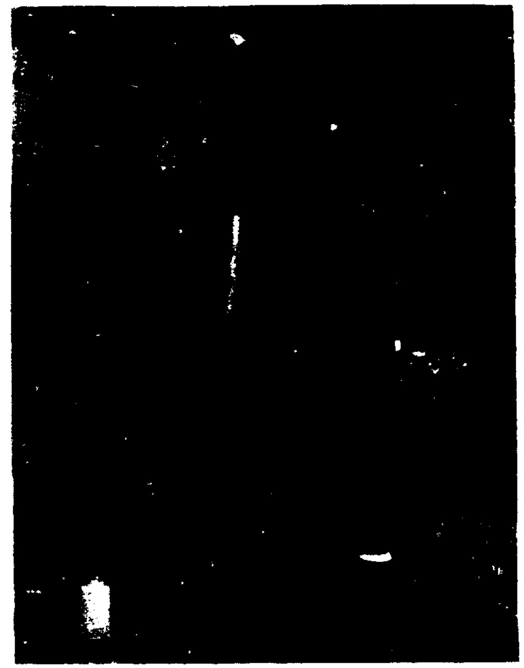
100% successful. Core samples were obtained from each event, and their locations are shown in Figure 5.2, 5.3, 5.4, and 5.5. Table 5.1 is a compilation of pertinent data concerning the individual samples from each event.

TABLE 5.1

CONCRETE CORE SAMPLE DATA

T-Lab Sample	Location	Weight (g)	Aliquot wt. (g)	dpm total sample	$\mu g/in^2$
		Double Tracks			
002	C-07	65.2	2.8	2.70×10^7	62
003	Q-11	72.8	6.7	1.20×10^7	27
004	I-02	39.0	4.9	7.2×10^7	165
005	K-17	91.3	7.5	3.45×10^6	7.9
006	A-19	86.	6.0	3.93×10^6	9
		Clean Slate I			
009	C-03	43.2	10.9	4.9×10^5	1.12
010	C-21	38.6	12.9	3.5×10^5	.80
012	K-03	91.0	20.4	5.66×10^4	.13
011	V-21	40.4	10.7	5,500	0.0
013	V-08	37.6		Lost in process	
014	V-03	52.3	12.3	6.2×10^5	1.42
		Clean Slate II			
018	SW	58.5	10.5	2.23×10^6	5.11
019	NE	85	17.5	1.74×10^6	3.96
021	NW	52	12	5.8×10^5	1.32
022	N Center	55	15.5	1.53×10^8	353.
023	S Center	51	31.5	1.31×10^6	3.02
020	SE	58.5		Lost in Process	
		Clean Slate III			
094	SW	60.5	60.5	4.6×10^6	10.5
095	W End Mid.	32.0	32.0	2.36×10^5	.54
096	S Middle	84.4	20.0	1.93×10^5	.44
097	N Middle	30.8	30.8	5.0×10^7	114.
098	NW	20.4	20.4	1.9×10^6	4.3
099	Middle	50.0	50.0	7.6×10^8	1740

Preparing concrete surface for coring. Spray can in right hand contains Dri-Stick, an adhesive, to hold one square foot mylar sheet on surface. This prevents scattering of cored powder outside the core hole or cross contamination from the surface around the hole. Note the 2-inch disk on the surface. This keeps Dri-Stick off the surface of the concrete where core will be taken. It is removed prior to placing the mylar sheet.



Performing the actual coring. The foot plate is placed over the mylar sheet and the weight of the operator keeps the star drill in place. The rubber boot acts as a seal to keep cored powder from escaping.

Figure 5.1a Concrete coring procedures. (Eberline Instrument photos)

Removing cored powder. A small spatula or spoon is used to pick up the loose powder and transfer it to a wide mouth polyethylene bottle. This bottle is capped and sent to the field laboratory for blending prior to chemical analysis.

Figure 5.1b Concrete coring procedures (continued). (Eberline Instrument photo)

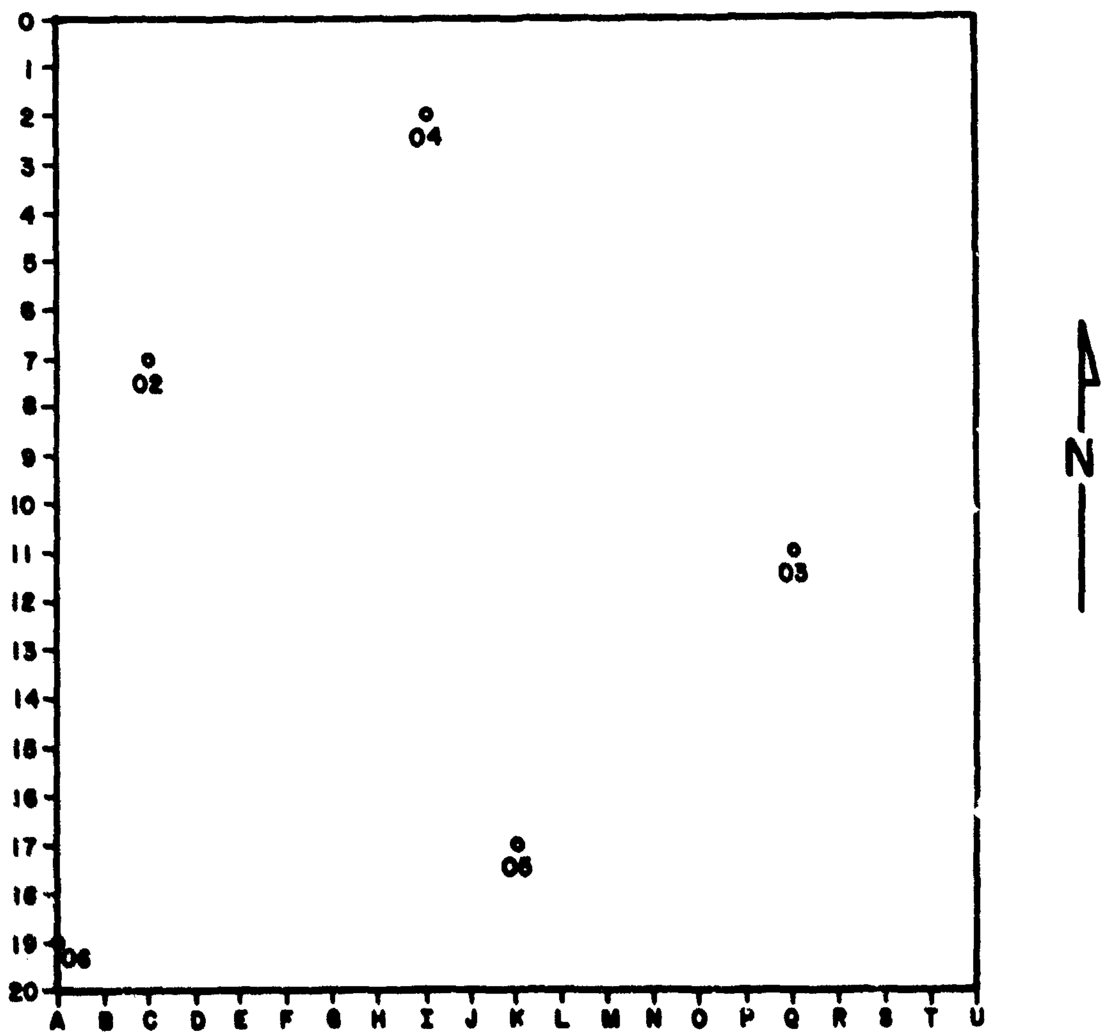


Figure 5.2 Location of concrete cores, Double Tracks.

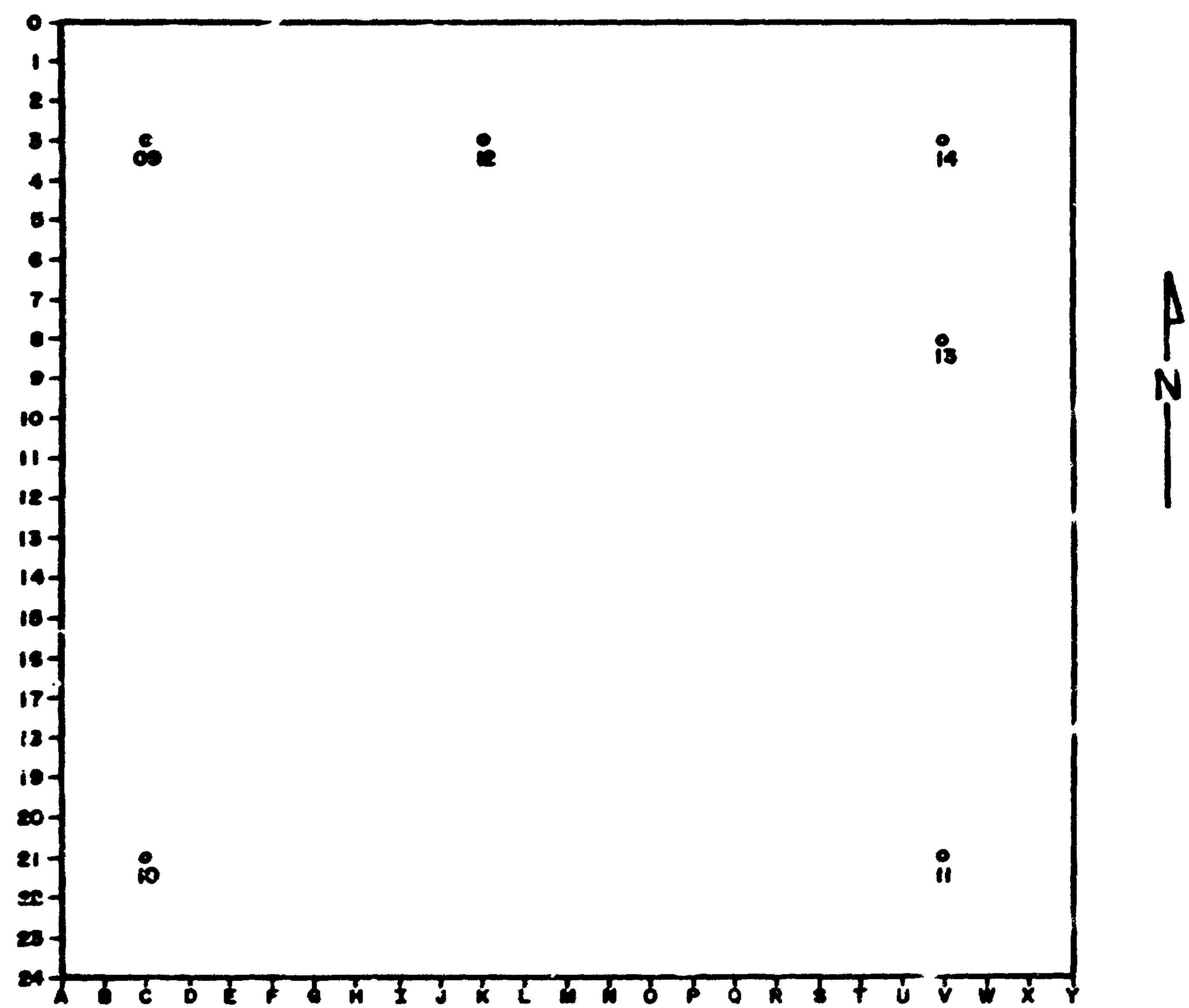


Figure 5.3 Location of concrete cores, CS I.

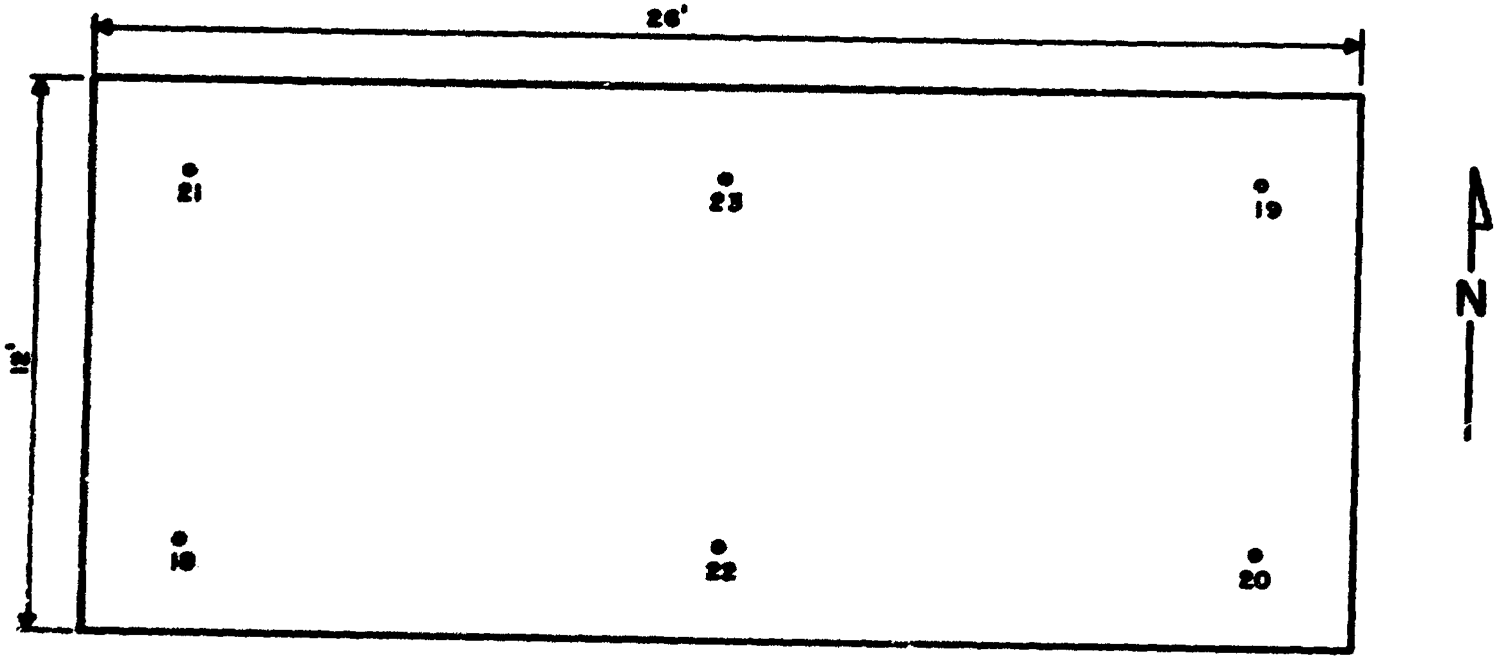


Figure 5.4 Location of concrete cores, CS II.

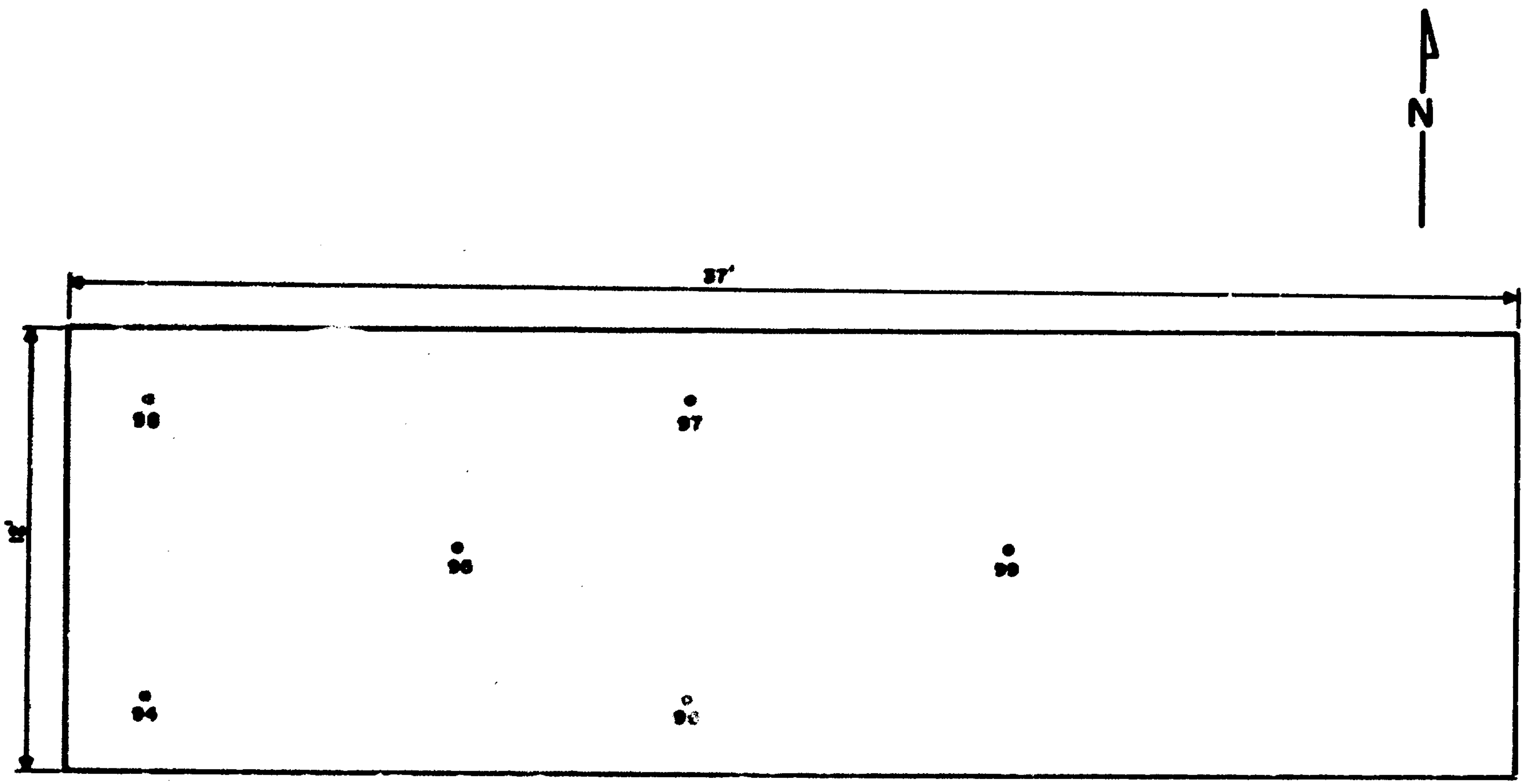


Figure 5.5 Location of concrete cores, CS III.

CHAPTER 6

ALPHA SURVEY AND GAMMA SURVEY ACTIVITIES

6.1 GENERAL

Alpha survey with the Eberline PAC-3G, gamma survey with the vehicle mounted gamma scanner, and the plutonium gamma probe have been described in detail in POR 2505 (Reference 3). Since Project 2.1 and 2.5 (Reference 3) overlap to some extent in the area from ground zero to 2,500 feet, alpha survey plots and vehicle mounted gamma scanner contours reported in Reference 3 are repeated for convenience (Figure 6.1 through 6.8).

In addition to these activities, numerous special applications and surveys were made, particularly very closein to ground zero, predominantly with gamma survey techniques, since contamination levels were very high. As well, some surveys were required at such time that weathering had degraded the plutonium contamination to the degree that alpha survey was totally unreliable.

Since these activities were carried out by both Project 2.1 and 2.5 personnel and in many cases were the result of observations or on-the-spot requirements, no attempt will be made to describe the instrumentation in the detail

or order that has been used in previous chapters. Rather, it is believed that a narrative format concerning each event, followed by a compilation of data gathered on each event will present a much clearer picture of these interrelated activities.

6.2 SPECIAL ACTIVITIES

6.2.1 Double Tracks. The discovery of extremely high contamination levels around DT GZ led to evaluation by the vehicle mounted gamma scanner and the PG-1. Attempts were made on D-Day to make measurements near the steel plate with the PG-1 and the vehicle-mounted gamma scanner, but levels were so high as to cause all equipment to peg. On D+4, PG-1 readings were made on the concrete pad, but the steel plate was still off scale. On D+8, PG-1 readings were taken again at the same location, as well as the steel plate at locations shown. A concentric circle survey with the PG-1 out to a radius of 100 feet was also made on D+8. The results of these surveys are shown in Figure 6.9.

6.2.2 Clean Slate I. The high levels observed on DT led to immediate evaluation of the CS I concrete pad as soon as possible after the event. The concrete pad was highly

contaminated by the event and ribbons of sand near the pad also showed high levels. The vehicle-mounted gamma scanner made measurements over each corner of the pad on D+1, and PG-1 readings were taken on D+1 and D+7. The results are shown in Figure 6.10.

6.2.3 Clean Slate II and III. In addition to mining, core sampling, and routine techniques already established for evaluation of the igloo structure area, the vehicle mounted gamma scanner conducted surveys in concentric circles around these areas, varying from a radius of 50 to 100 feet in 10-foot increments for CS II on D+4 and from a radius of 72 to 200 feet in 16-foot increments for CS III on D+1. The details and resultant readings from these surveys are shown in Figures 6.11 and 6.12.

6.3 DISCUSSION AND RESULTS

Although alpha survey is a well established and accepted procedure for the evaluation of plutonium deposition on the ground, its limitations are also well known. The contamination levels encountered in the GZ areas were either beyond the limits of alpha survey radiacs or were degraded by weathering or deposition depth to unacceptable limits. Alpha readings could be made with a pre-production model

of a Ruggedized Alpha Survey Probe (Eberline RASP-1) which could be collimated and thus reduce the sensitive area of the probe by a factor of 75. However, the validity of the readings could not be accepted, since the self absorption effect of the relatively thick layer of plutonium could not be calculated.

In the case of the plutonium gamma survey technique, much valuable data was gained close-in that would have been otherwise lost. The gamma scan technique was not intended to be a truly quantitative measuring device in Roller Coaster, but as the operation proceeded, the value of this technique became more obvious, and more credence was placed on its measurements. Project 2.5 established ratios for both the vehicle-mounted gamma scanner and the PG-1 probe in relation to the PAC-3G as follows:

PAC-3G to VMGS = 20:1

PAC-3G to PG-1 = 60:1 .

These factors are considered reliable and can be used for further correlation, once an accepted correlation factor for conversion of PAC-3G readings is established.

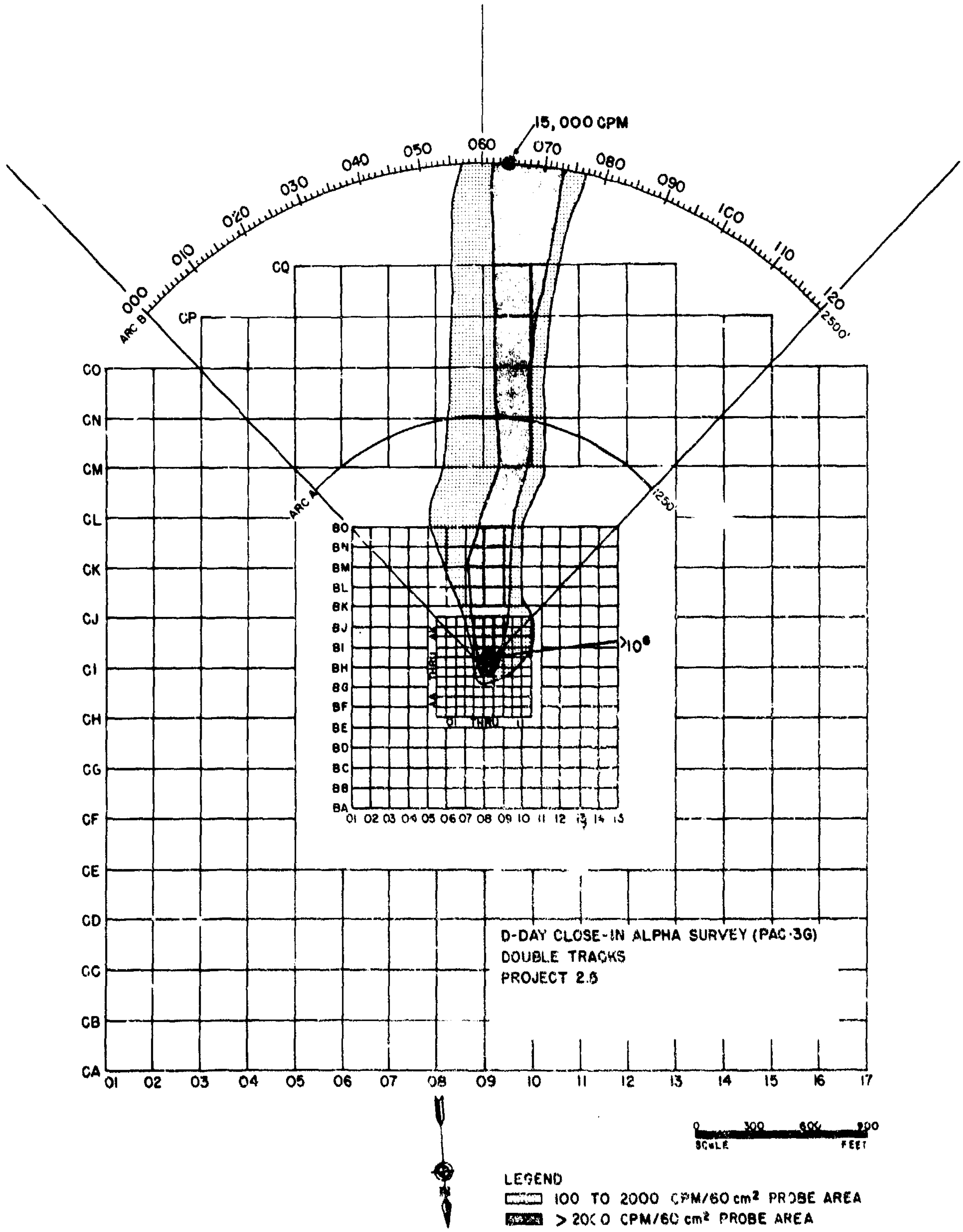


Figure 6.1 Close-in alpha survey, DT.

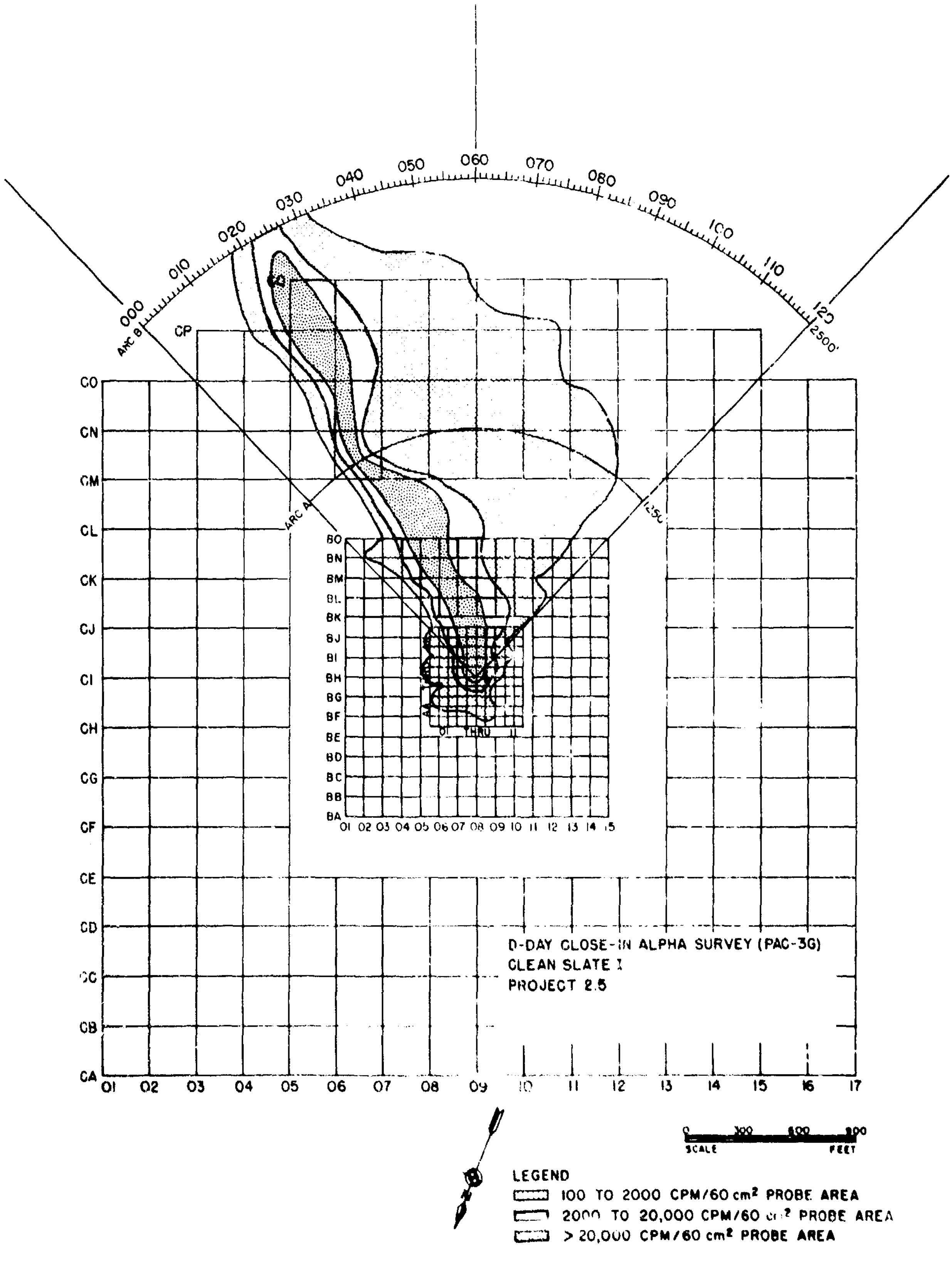


Figure 6.2 Close-in alpha survey, CS I.

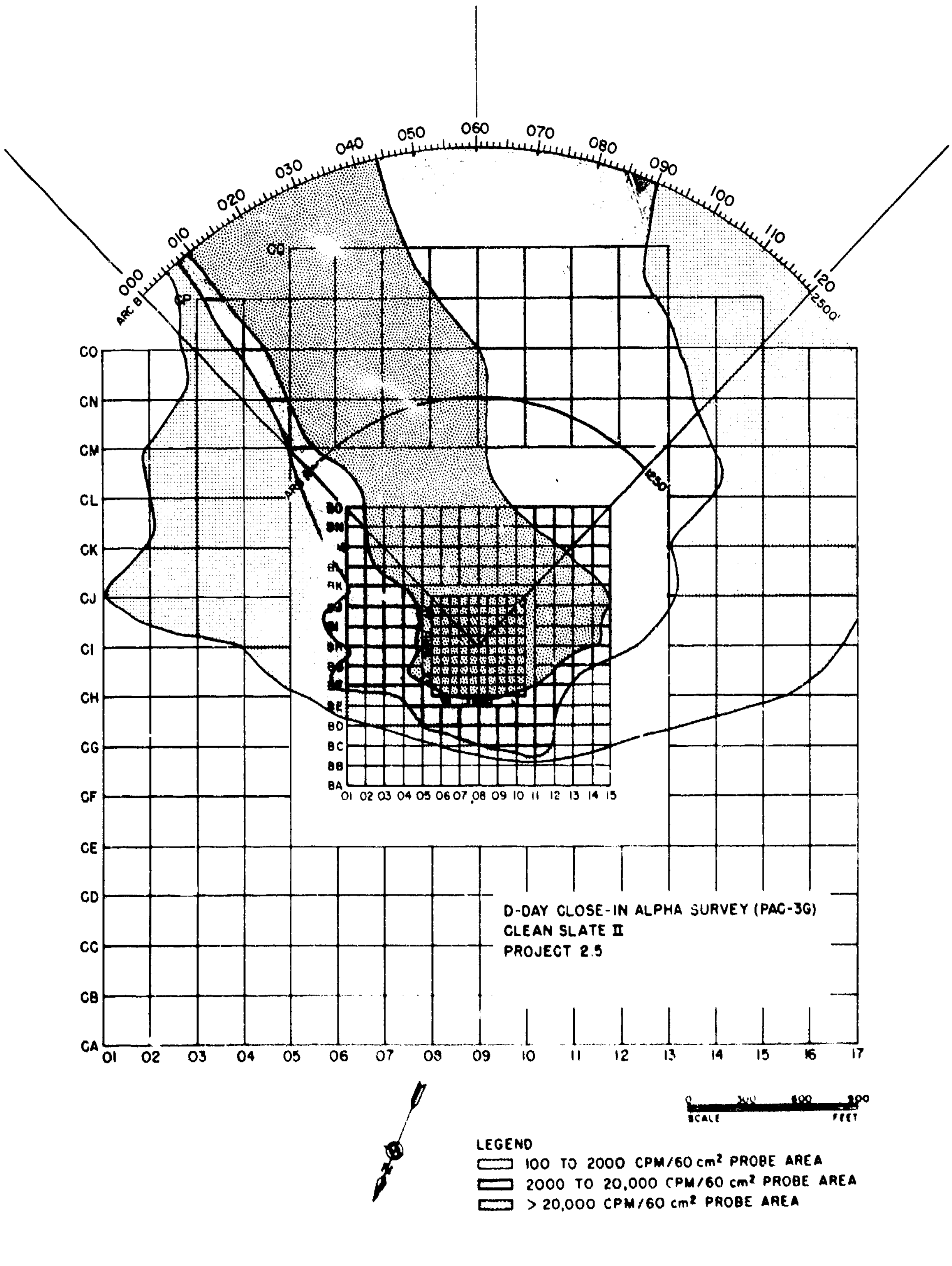


Figure 6.3 Close-in alpha survey, CS II.

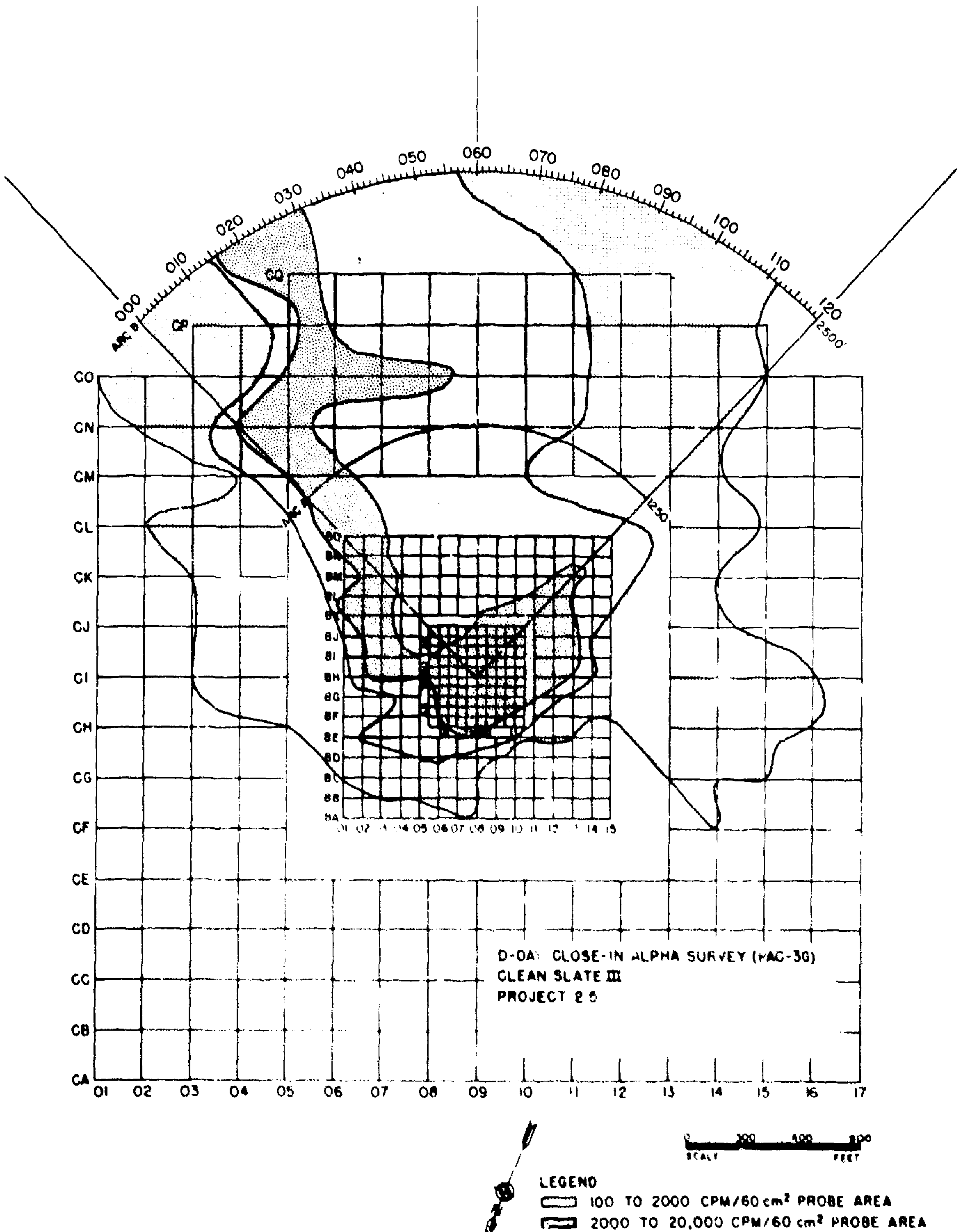


Figure 6.4 Close-in alpha survey, CS III.

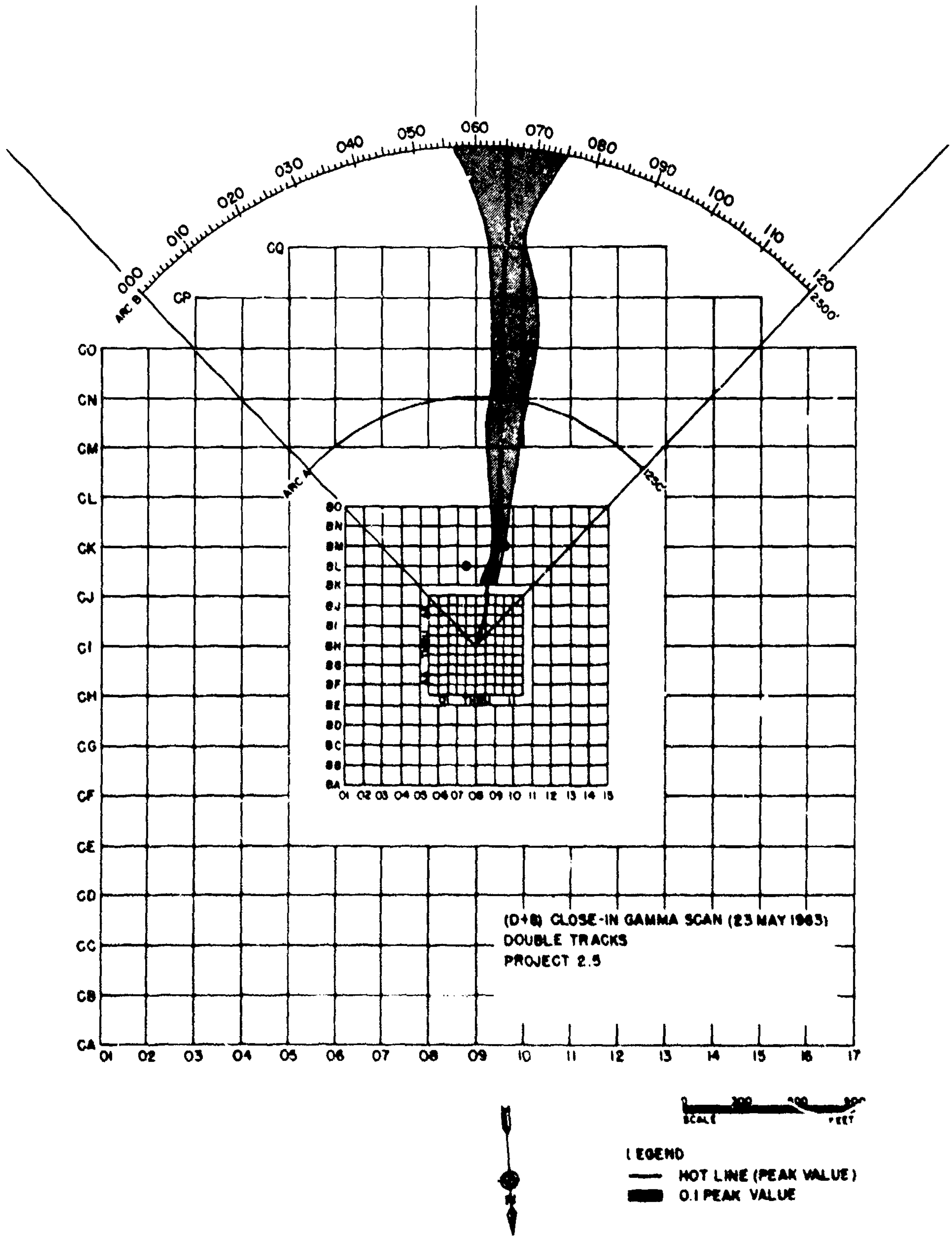


Figure 6.5 Close-in gamma survey, DT.

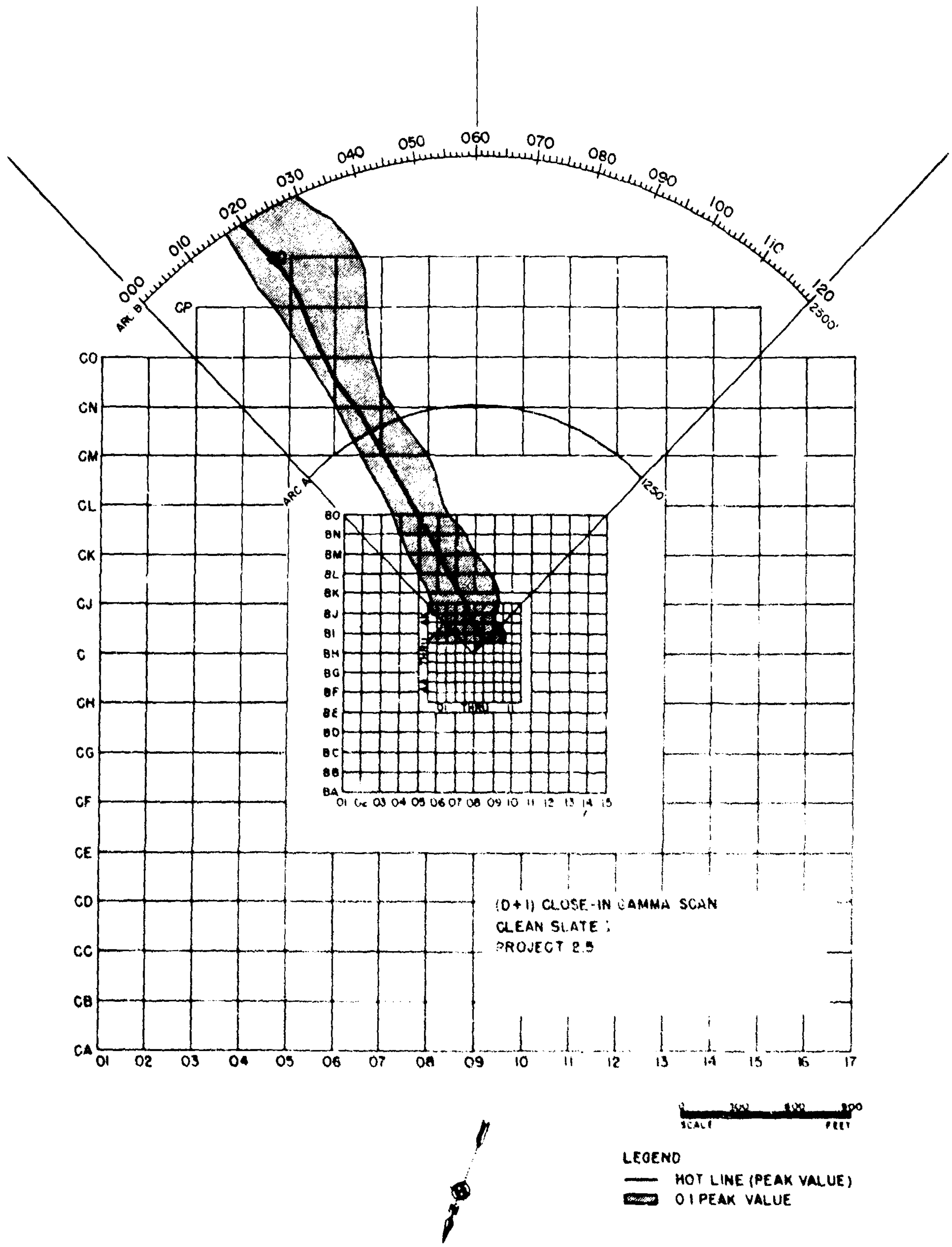


Figure 6.6 Close-in gamma survey, CS I.

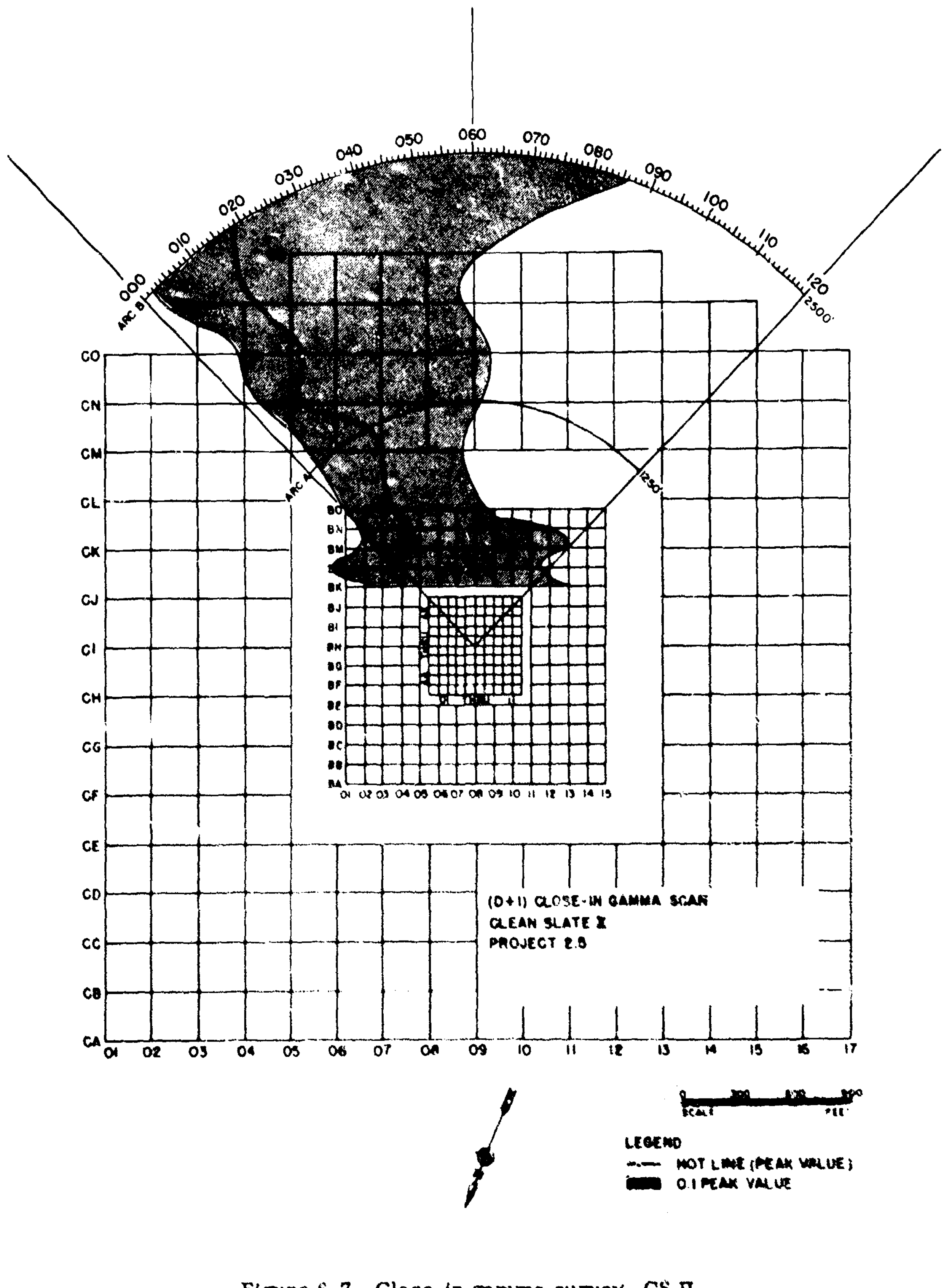


Figure 6.7 Close-in gamma survey, CS II.

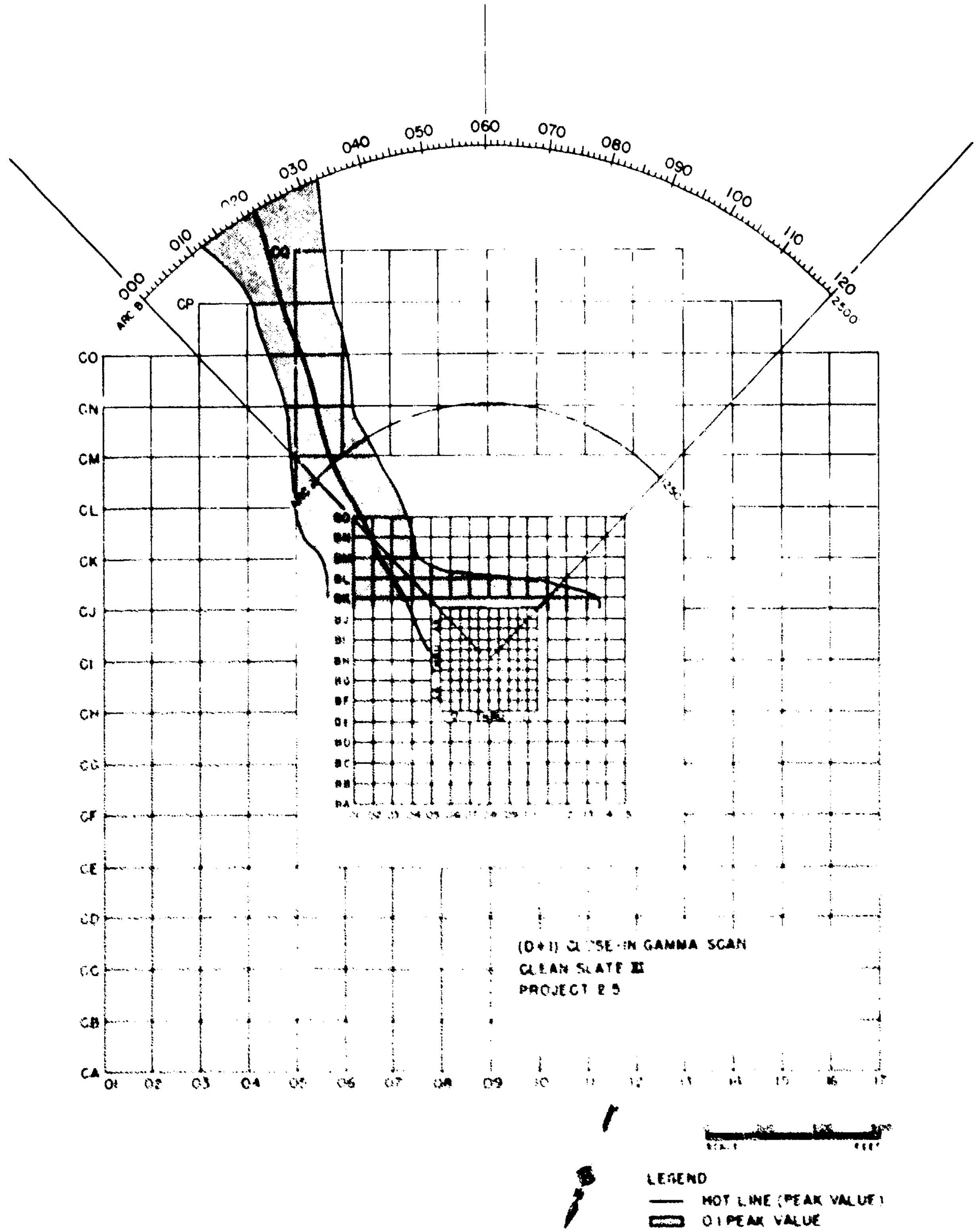


Figure 6.8 Close-in gamma survey, CS III.

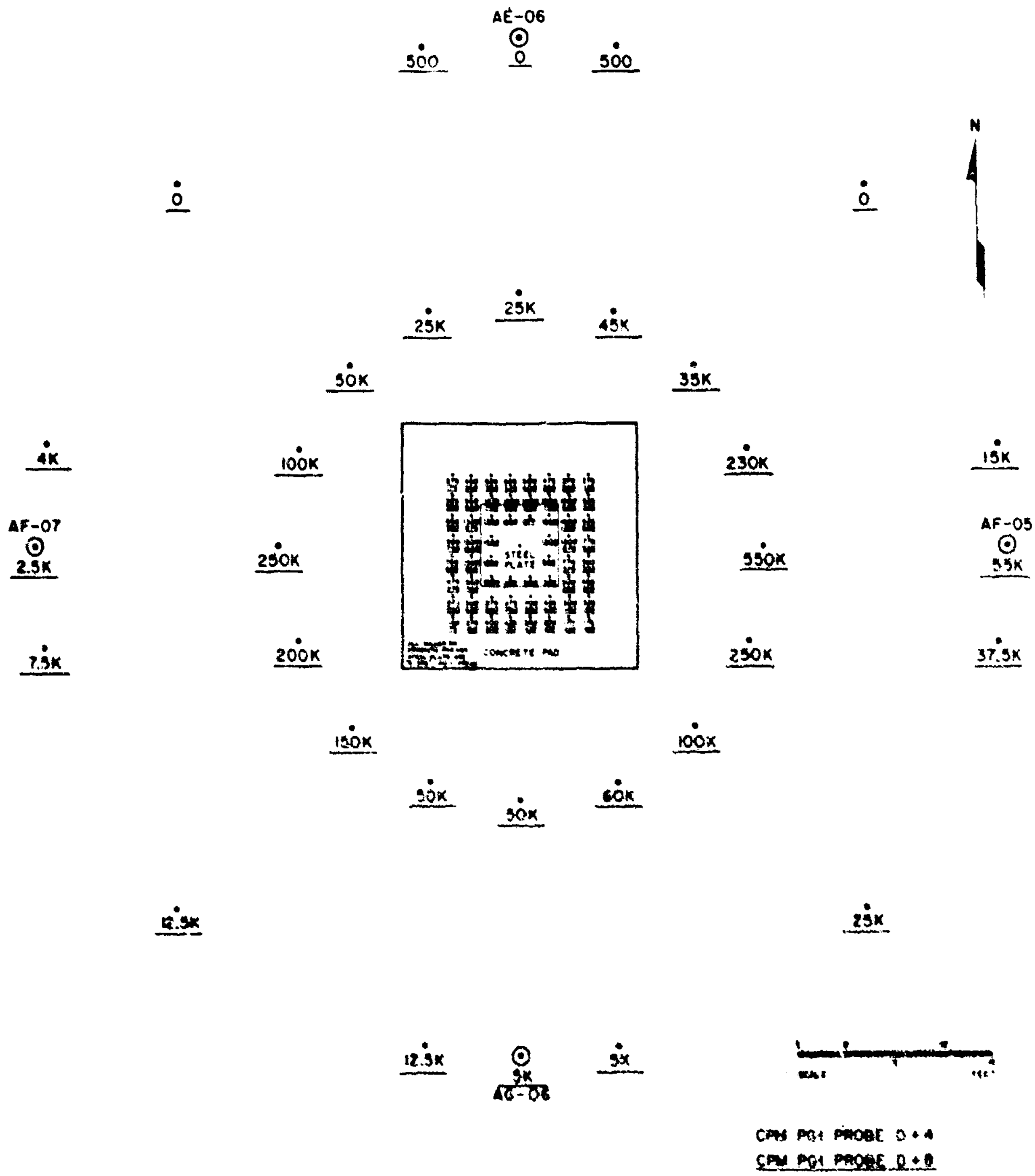
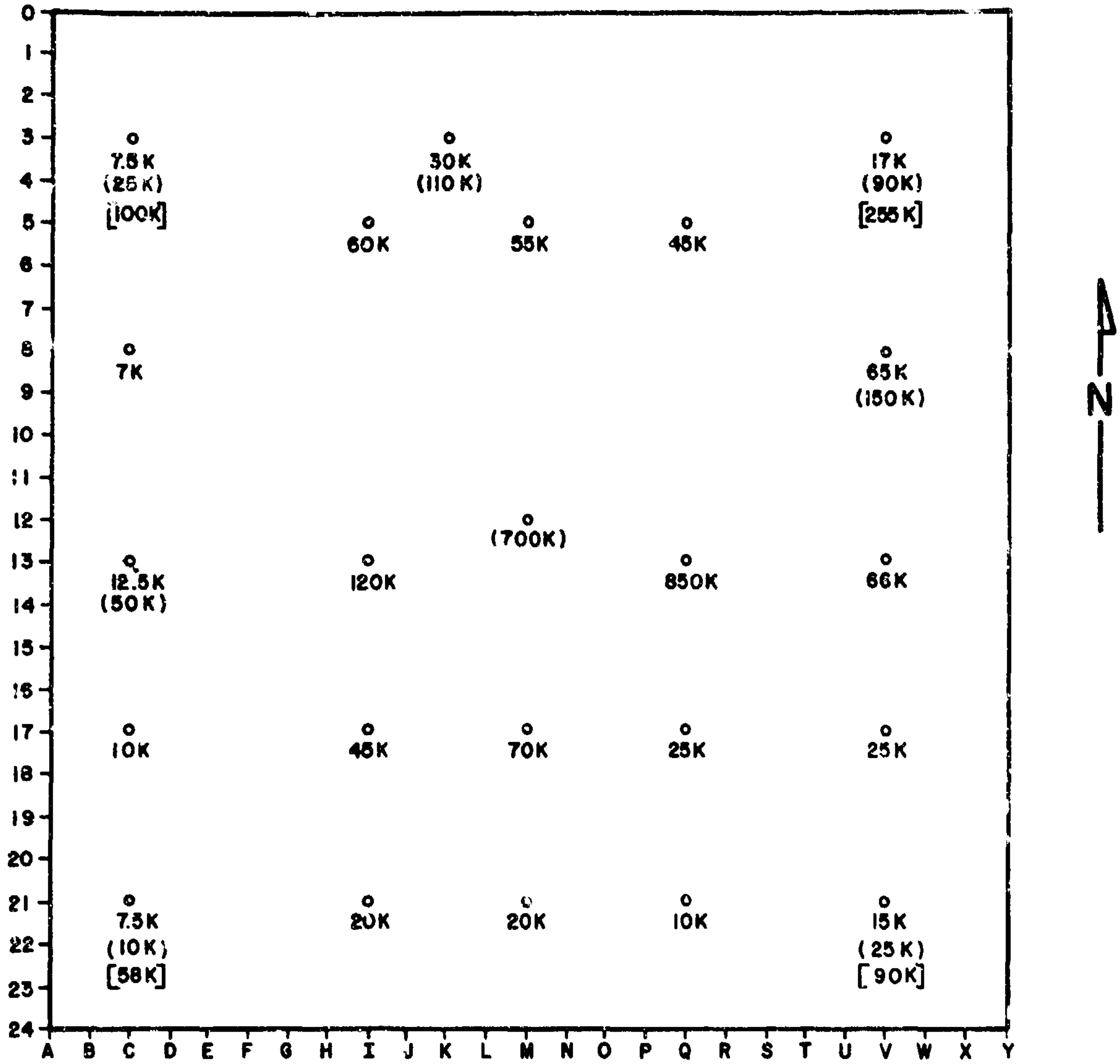


Figure 6.9 Gamma survey on DT concrete pad, steel plate, and close-in area.



CSI CONCRETE PAD MEASUREMENTS

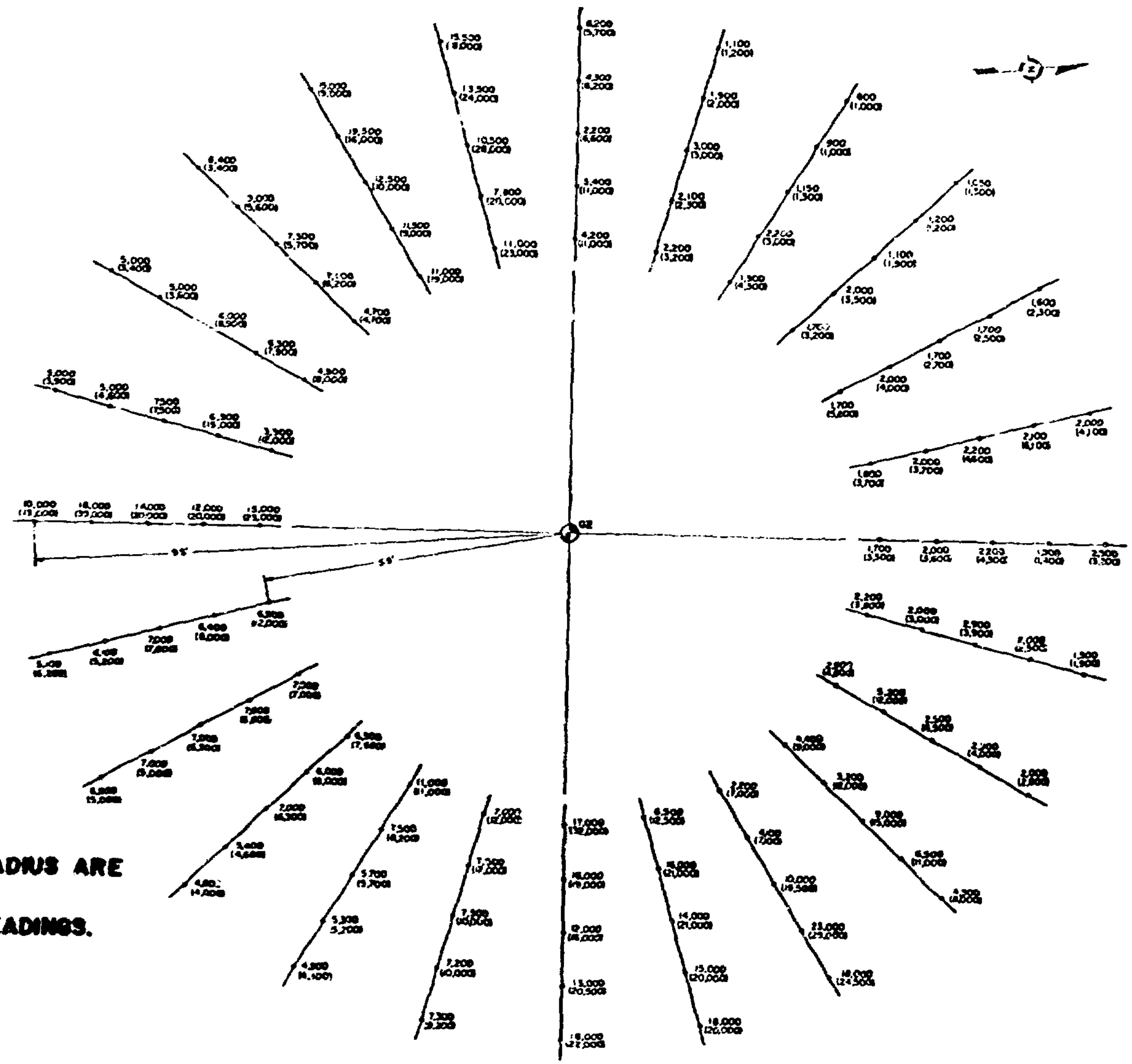
NET PG I READINGS 6/1/63 (D+7)

" (" ") 5/26/63 (D+1)

" [VMGS "] 5/26/63 (D+1)

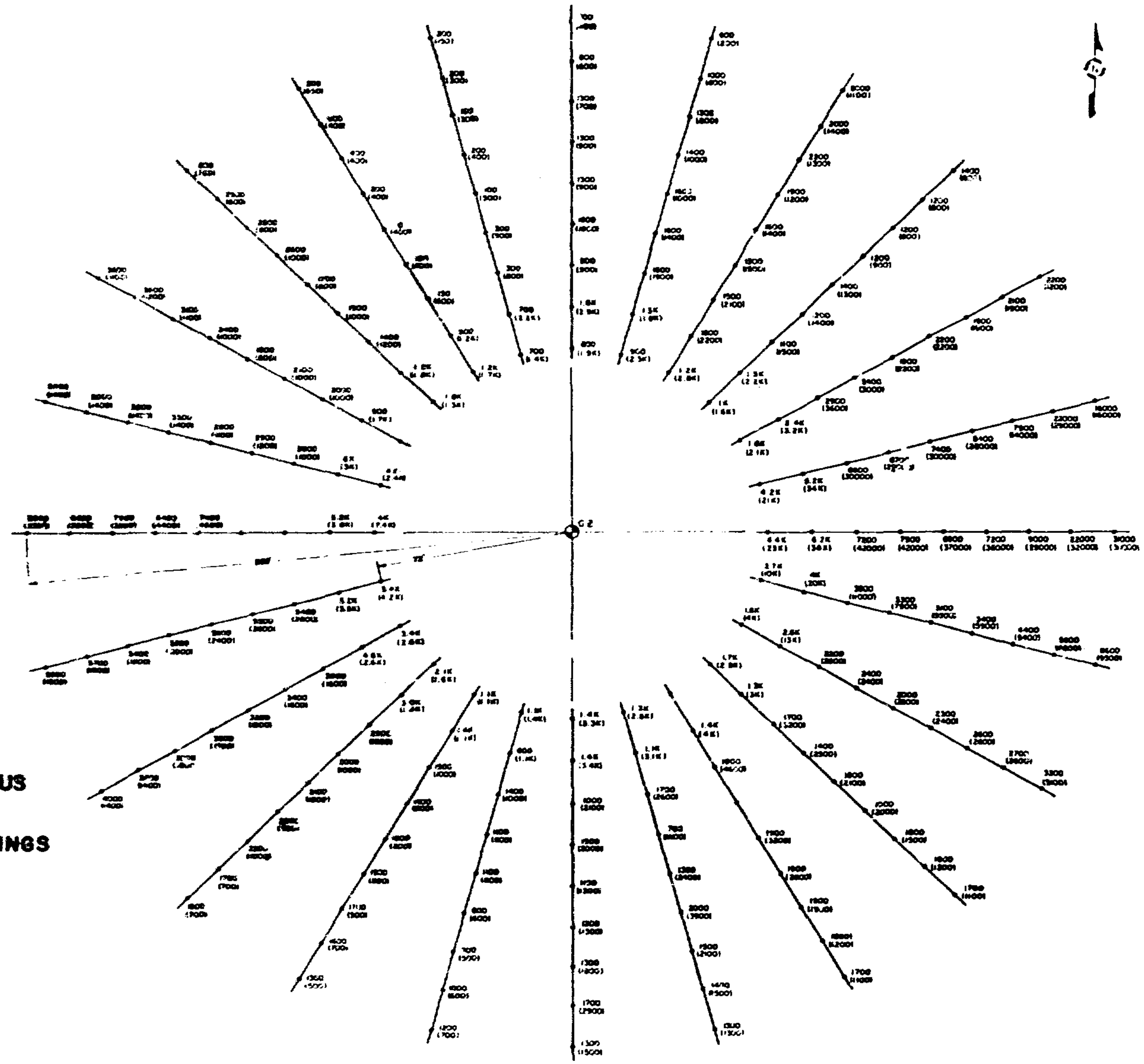
NOTE: ALL READINGS IN Pu^{239} CHANNEL

Figure 6.10 Gamma survey of CS I concrete pad.



NOTES:
1. ALL STATIONS BEYOND 55 ft. RADIUS ARE TO BE AT 10' INTERVALS.
2. ( ) INDICATES AM 24H READINGS.

Figure 6.11 Concentric gamma survey by vehicle ' anner, CS II.



NOTES:

1. ALL STATIONS BEYOND 72ft. RADIUS ARE TO BE AT 16' INTERVALS.

2. (   ) INDICATES Pu^{239} READINGS

Figure 6.12 Concentric gamma survey by vehicle scanner, CS III.

CHAPTER 7

FOLLOW-ON DEBRIS STUDY

7.1 BACKGROUND AND OBJECTIVES

The observations of the very high levels of contamination associated with the 8 foot by 8 foot steel plate used as a GZ point for the Double Tracks event, and subsequent evaluation of the limited data obtained from it, led to the establishment of a special project termed Roller Coaster Follow-On. This project began work in November, 1963 and this chapter will discuss the salient points of this work, with a brief description of instrumentation and procedures, the results, conclusions, and recommendations.

Briefly stated, the objectives of the Follow-on work were:

1. Recover DT steel plate and a part of CS II and CS III metal igloo debris buried at the Tonopah Test Range, Nevada.

2. Investigate plutonium deposition patterns and amounts fixed to metal surfaces, employing radiochemistry, radioautography, metallurgy, and field alpha and low energy X-ray and gamma counting.

3. Correlate existing deposition patterns and amounts to an estimate of original scavenging.

4. Provide report with raw data.

5. Insure protected storage for debris for possible future research programs.

The scope of these objectives was considerably expanded from time to time, since greater interest was expressed as data began to indicate the importance of the scavenging effect.

7.2 INSTRUMENTATION

The contamination level on the Double Tracks plate was known to be high, but levels on the igloo debris were unknown. The size of individual pieces also had to be considered since the Double Tracks plate was 8 feet square and weighed approximately 2,600 pounds (Figure 7.1). All that was known of igloo debris was that it consisted of

large, mangled pieces of corrugated iron (Figure 7.2). Therefore, plans were made to use the various techniques of radiation detection, radioautography, and radiochemistry, in a manner best fitting the situation at the time.

The basic approach to quantitative plutonium evaluation on the DT steel plate was through radioautography. X-ray film (14 inches by 17 inches) was used for qualitative evaluation, while Dupont 555 dosimetry film was used for quantitative evaluation, to measure the 60-Kev gamma emission from Am^{241} by density correlation. Since the accuracy of film dosimetry would depend on the Pu^{239} - Am^{241} ratio remaining constant, it was necessary to determine if this were true. A scaffolding framework was built to allow the detector from the vehicle-mounted gamma scanner to be accurately moved in small increments, thus scanning the entire plate in detail. The face plate of the detector assembly was modified to provide the detector crystal only a 1/2-inch diameter collimated view of a portion of the DT plate. The detector assembly was connected to the installed electronics in the vehicle, with one man positioning the detector, and one man reading and recording both the Pu^{239} and Am^{241} channel readings.

After recovery of the igloo debris at Tonopah, PAC-3G alpha counters, PG-1/PAC-1S plutonium gamma detecting radiacs, thin end-window geiger counters, and the RASP-1 (Ruggedized Alpha Survey Probe) were all used to roughly screen the debris (Figure 7.3). None of these portable devices were entirely suitable, but the PG-1/PAC-1S appeared to have the best capability for the problem at hand. It was decided that this would be the primary instrument for evaluation of the igloo debris. The PAC-3G was used only for contamination control.

The techniques and equipment of radiochemistry were used to evaluate small samples of igloo debris for total plutonium to provide correlation with PG-1 readings and film density. These pieces were cut from debris with a sabre saw (Figure 7.4). In addition, debris from a decontamination exercise on the DT plate was analyzed completely.

7.3 CALIBRATION

The gamma scanner was calibrated with standard plutonium sources in the same manner as described in Reference 3. Since the gamma scan was to be only relative in validating a constant Pu to Am ratio, no attempt was made to obtain

high level plutonium sources for quantitative evaluation.

Calibration of the PG-1/PAC-1S was accomplished with known 2 π emission plutonium sources, to insure that all measurements were related to the same baseline. This was not true calibration, since contamination levels of importance were far in excess of existing sources, and some non-linearity was known to be inherent in the PG-1 probe. To obtain confident correlation (or calibration) factors, igloo pieces smaller than the active area of the PG-1 detector were secured with varying activity, and the PG-1 reading in cpm from each compared to total Pu deposition in micrograms as determined by radiochemistry. A graph of this data (Figure 7.5) provided the basis for a cpm-microgram conversion table (Figure 7.6).

7.4 PROCEDURES AND OPERATIONS

After excavation of the DT steel plate and CS igloo debris at Tonopah, the material was packaged and transported to previously prepared facilities at the Nevada Test Site. The steel plate was placed in a specially fabricated steel tray to prevent spread of contamination. The scaffolding was erected and Pu - Am measurements were made every

2 inches in both directions on the steel plate (Figure 7.7). In all, 2,209 measurements were made and recorded for the steel plate in addition to many other experimental measurements.

The entire plate was covered with 42 sheets of 14 inch by 17 inch X-ray film and exposed for 19 hours (Figure 7.8). This was a purely qualitative exercise to determine distribution patterns on the plate, and the results were more than impressive. Figure 7.9 is a transmitted light photograph of the resultant 8-foot-square radioautograph.

Four thousand four hundred Dupont 555 dosimetry film packets, shielded with 1/16 inch aluminum, were placed so as to cover the entire plate and were exposed for 16 hours (Figure 7.10). These packets were developed and read in four places for density resulting from exposure to the 60-Kev gamma emission from Am^{241}.

Igloo debris was scanned by placing the PG-1 probe on the metal surface, recording the reading, moving the probe a distance about equal to its diameter and successively repeating this process until the entire surface had been scanned. Forty-one individual pieces of the igloo debris were scanned in this manner. Tables 7.1 and 7.2 are a

compilation of the data gathered.

X-ray film placed on the igloo debris showed a very splotchy and uneven deposition (Figure 7.11). Another interesting aspect clearly illustrated by the radioautography and verified by PG-1 measurements was the directional deposition effects. Figure 7.11 is a photo of an X-ray radioautograph with the dark areas indicating heaviest contamination levels. These areas were parallel to corrugations and the fact that deposition occurred repeatedly on the same side of the corrugations indicates that the plutonium was traveling in straight lines, impacting with greatest concentration in areas perpendicular to the line of travel.

In order to determine the degree of plutonium fixation, a portion of the DT plate and selected igloo debris pieces were subjected to similar decontamination procedures, with measurements being taken before and after application (Figure 7.12). Alcohol, lacquer thinner, paint remover, and water were applied with scrubbing brushes, wire brushes, and steel wool. It was found that plutonium on the plate was loosely fixed, while that on the igloo debris was very tightly fixed. It was observed that when high levels of contamination on igloo

debris were associated with an easily identified hard ceramic-like scale; the scale would flake off, carrying most of the plutonium with it. When this scale was absent and high levels were found, the plutonium was more tightly fixed.

7.5 DISCUSSION

The most important point to be emphasized and kept in mind in any discussion of the Follow-on work is that resultant numbers cannot be absolute. There are so many unknowns associated with this work that cannot be resolved, that even relative values may be questionable. The original deposition cannot be accurately determined because the effects of weathering, burial, physical treatment by heavy machinery, location at time of detonation, and many other factors cannot be properly evaluated. In view of these variables, numbers can only be estimated based on data gathered after the fact, correlated with prior Roller Coaster data, and coupled with judgement and experience gained during the course of this project.

7.6 RESULTS

7.6.1 Double Tracks Steel Plate. The original estimate of plutonium on the steel plate was approximately 20 grams, based on gamma survey techniques. Radiochemical analysis of five steel plugs resulted in revision of this estimate to 50 grams.

It was anticipated that film dosimetry would provide a more accurate estimate of total deposition based on the correlation of film density with plutonium deposition in micrograms per unit area. Therefore, film packets were placed, exposed, measured, and recorded. In all, 17,600 separate density readings were recorded with densities ranging from 0.00 to 1.89. Small igloo debris samples were placed on similar film in order to provide film densities which would relate to $\mu g/cm^2$. These small pieces contained as much as 1,000 $\mu g/cm^2$, and yet the maximum film density from exposures equivalent to that of the DT plate was approximately 0.50, which is a factor of 4 low for reasonable correlation. Therefore, these film data did not supply the information desired and are not reported.

Another approach to estimate the amount of original deposition can be utilized. Study of Roller Coaster data concerning the immediate GZ area (steel plate and concrete pad) together with PG-1 measurements after excavation, gamma scanner data before and after decontamination measures, and radiochemistry of the decontamination debris led to the following line of reasoning:

1. On D-day (DT), neither the steel plate nor the concrete pad could be measured with available instrumentation.
2. On D+4, the concrete pad and adjacent area could be measured with the PG-1 (Figure 7.13). The steel plate could not be measured.
3. On D+8, the steel plate and concrete pad were measured with the PG-1. The minimum reading on the steel plate was 500 K in the SE corner. The maximum reading with the PG-1 was 2,000 K. Since the PG-1 was off scale at this point (2,000K) at D+4 and read 500 K at D+8, there must be a factor of 4 reduction from D+4 to D+8. (Figure 7.13).
4. PG-1 readings after burial and excavation of the

plate were reduced by a factor of 2 (Figure 7.14) resulting in total degradation by a factor of 8.

5. The decontamination exercise on 100 in^2 of the plate removed 56% of the deposited plutonium. This was determined by gamma scan survey (Am^{241} only) before and after decontamination (Figure 7.12). Radiochemistry of debris excluding paint brushes, wire brushes, and scrubbing brushes determined that 136 mg Pu were contained therein. Adding 4 mg as an estimated Pu content of paint brushes then 140 mg were removed. This is 56% of the total which is 250 mg/100 in^2. However, the area decontaminated is not truly representative of the entire plate, being above average (as determined by gamma scan) so the total was reduced by a factor of 2 or to 125 mg/100 in^2, equal to 1.25 mg/in^2. Thus, for the entire plate, 1.25 mg × 9216 in^2 = 11,520 mg = 11.52 g indicated.

6. Accounting for a total of 11.52 grams remaining on the steel plate and accepting a factor of 8 degradation as justified in subparagraphs 1 through 4

above, then a minimum of 92.16 grams were originally deposited on the plate.

7. This is a very conservative estimate, since no degredation factor is included for the time period from D-day to D+4. This factor is estimated as a minimum of 2 to a maximum of 6. Accepting a factor of 2 due to initial weathering, the amount originally deposited on the plate would be 184.3 grams.

<u>7.6.2 Igloo Scavenging</u>. It is much more difficult to make a reasonable estimate of the igloo scavenging effect than to estimate scavenging by the DT steel plate. The steel plate was recovered completely, and its orientation is known with certainty.

The reverse is true of igloo debris. Good conversion and correlation data exist, but only a certain percent of the total igloo area from unknown locations is available, and it would not seem reasonable to attempt to reassemble the entire igloo from each event. Even though more than

16% of the total igloo area was recovered and measured, there is no assurance that this is a representative sample of the whole. Too, only one device contained plutonium and its location in the center of the igloo resulted in a variance in distance from the point of detonation to the points of contact. The igloo door, which was about 18 1/2 feet from the plutonium bearing device in CS III, had relatively low levels of contamination. Other pieces of corrugated iron which must have been closer to the detonation had extremely high levels. Pieces of corrugated iron identified by the half-circle cutout as being from the vent area of the CS II and CS III were also relatively low in contamination. The plutonium bearing device in DT was only about 18 inches from a metal surface, while in CS II and CS III, the minimum distance to a metal surface was 6 feet. Thus, it is assumed that the scavenging effect of the metal is somewhat dependent on the proximity of the surface as well as other factors such as temperatures, pressures, and chemical and physical state, etc. This assumption suggests that only a portion (or band) of the igloo was subjected to maximum scavenging effectiveness.

With these factors in mind, as well as the unknowns associated with the treatment of the debris, weathering, scouring action, and others, and using the data in Tables

7.1 and 7.2, the following estimates are made of igloo scavenging effects. These estimates are based on the two simplest approaches and are believed to be very conservative. The reader may apply more sophisticated treatment if so desired, since all data is contained in Tables 7.1 and 7.2.

CS II - Method I - total area x average deposition

This method assumes that a representative sample was obtained. Thus, with a liner area of 70,573 in^2 and the average deposition $\simeq$ 27.5 $\mu g/in^2$, total deposition was 1,940,757.5 μg or 1.94 grams.

- Method II

This method assumes that a representative sample was not obtained, but that the debris recovered contained a representative sample. Therefore, approximately equal areas of high, medium, and low deposition levels were selected and averaged, to obtain an average $\mu g/in^2$ factor.

	Area (in^2)	$\mu g/in^2$	Average
High	252	287	172.2
	360	68.5	
Medium	390	47	44.1
	368	41.2	
Low	143	4.0	4.3
	506	5.5	

Average deposition level - 73.5 μg/in^2

70,573 in^2 x 73.5 μg/in^2 = 5,187,115.5 μg ≅ 5.2 grams

Summary: One piece of debris, out of 22, measured 287 μg/in^2. The next highest level was 68.5 μg/in^2. It is reasonable to expect that other pieces should be in the 200 to 300 μg/in^2, and therefore, the entire sample is not representative. It is believed that an estimate of 5.2 grams has a greater degree of confidence than 1.9 grams.

CS III - Method I

Igloo area - 92,288 in^2

Average deposition - 160 μg/in^2

Total deposition - 14,766,080 μg = 14.77 grams

- Method II

	Area (in^2)	μg/in^2	Average
High	450	636	509.5
	576	383	
Medium	320	146	139.5
	391	133	
Low	435	2.1	3.7
	1800	5.3	

Average deposition level - 219 μg/in^2

92,288 x 219 = 20,211,072 μg = 20.21 grams

Summary: The total debris from CS III appears to be closer to a representative sample but it is believed that

an estimate of 20.21 grams has greatest confidence.

Both cases are only extrapolations of data points as to what remains on the collected igloo debris at the time of measurement. A valid method of estimating original deposition is not known.

7.6.3 Metallographic Studies. Metallurgical examinations have been made on both the DT plate deposition and the igloo metal debris, but results to date have been mainly in terms of microphotographs of sections and some speculation as to the methods of deposition.

The Double Tracks plate plugs were sectioned by CMF Division, Los Alamos Scientific Laboratory (LASL). Metallographic examinations performed at LASL on these sections were reported (Reference 4) to indicate that the plutonium oxides were probably deposited by three methods:

1. The attachment of a slag-like compound, probably plutonium oxides, on the surface of the steel which is loosely bound.
2. The entrapment of debris, probably oxides and molten metal, in crevices and indentations caused by fragmentation damage to the surface of the plate.

3. There appeared to be a vapor deposit of a very thin layer of metal on the surface of the plate.

All three methods resulted in deposition in the top 5 mils of the surface of the plate, except where surface damage by fragmentation had penetrated deeper.

The metal igloo debris was examined in a like manner, but unfortunately, none of the sections cut through a definite layer of plutonium contaminated metal. Electron and X-ray diffraction studies are in progress at the Dow Chemical Company, Rocky Flats Plant, Colorado.

A point worthy of note was observed during igloo metal studies. It was found that the galvanized layer on the corrugated iron was not tightly attached, and sometimes, the entire layer of galvanization was removed by blast spalling or some other undetermined method and was in fact removed from both sides of the metal. A further examination of the metal at NTS indicated that the plutonium fixed to the bare iron surface was more tightly bound to the iron than if deposited on a galvanized surface. Complete evaluation of this phenomena would require additional studies.

Figure 7.15 is a microphotograph of a section of a DT steel plate plug, showing the loose slag-like oxide.

Figure 7.16 is a microphotograph of a different section, showing the oxides trapped in a slight dent. These two photos were provided by LASL (Reference 4).

TABLE 7.1

CLEAN SLATE II EVENT

Sample #	Dimensions (in inches)	Area (in sq in.)	Total Pu (in mg.)	Pu ug/in^2	No. of measurements
A- 1	19 x 15	285	1.71	6	averaged by scan
A- 2	13 x 11	143	0.572	4	" " "
A- 3	18 x 14	252	72.2	287	68
A- 4	20 x 18	360	24.65	68.5	130
A- 5	18 x 12	216	6.102	28.3	71
A- 6	13 x 12	156	0.624	4.	averaged by scan
A- 7	26 x 15	390	18.25	47	112
A-10	25 x 21	525	9.752	18.6	165
A-11	23 x 22	506	2.750	5.5	101
N- 1	24 x 21	504	3.22	6.4	98
N-12	23 x 16	368	15.137	41.2	110
N-13	29 x 14	406	2.429	6.	107
N-14	36 x 14	504	2.607	5.2	95
N-15	34 x 20	680	2.72	4.	117
N-16	18 x 16	288	1.5	5.2	10[illegible]
N-17	36 x 13	468	1.872	4.	averaged by scan
N-18	43 x 18	774	20.085	26.	168
N-19	51 x 20	1020	6.233	6.	282
N-20	75 x 40	3000	2[illegible].	7.	averaged by scan
N-21	20 x 18	360	4.473	12.4	52
N-22	22 x 17	374	2.245	6.	108
VO 1	32 x 21	672	8.060	12	99
Totals:		12251	227.191	average 27.5	1986

Area of CLEAN SLATE II Igloo liner, 70573 in^2

TABLE 7.2

CLEAN SLATE III EVENT

Sample #	Dimensions (in inches)	Area (in sq in.)	Total Pu (in mg.)	Pu ug/in^2	No. of measurements
B- 1	31 x 16	496	180.	363	134
B- 2	24 x 24	576	221.13	383	199
B- 3	20 x 16	320	46.845	146	114
B- 4	29 x 15	435	0.92	2.1	100
B- 6	20 x 20	400	9.65	24.	142
B-10	23 x 17	391	52.	133	118
B-11	24 x 21	504	166.2	337.	148
DF- 1	35 x 12	420	3.63	8.65	107
N- 2	48 x 30	1440	13.127	9.1	277
N- 3	50 x 36	1800	9.524	5.3	241
N- 4	15 x 13	195	15.667	80.5	34
N- 5	54 x 22	1188	52.923	44.5	245
N- 6	27 x 15	405	43.917	101	124
N- 7	36 x 30	1080	9.9	9.2	249
N- 8	54 x 42	2268	17.086	7.5	303
N- 9	36 x 30	1080	345.89	320	296
N-10	17 x 10	170	60.043	353.8	35
N-11	30 x 15	450	285.493	636	120
DF- 2	43 x 12	516	40.682	78.7	131
Totals:		14134	1574.627	average 160	3117

Area of CLEAN SLATE III Igloo liner, 92,288 in^2

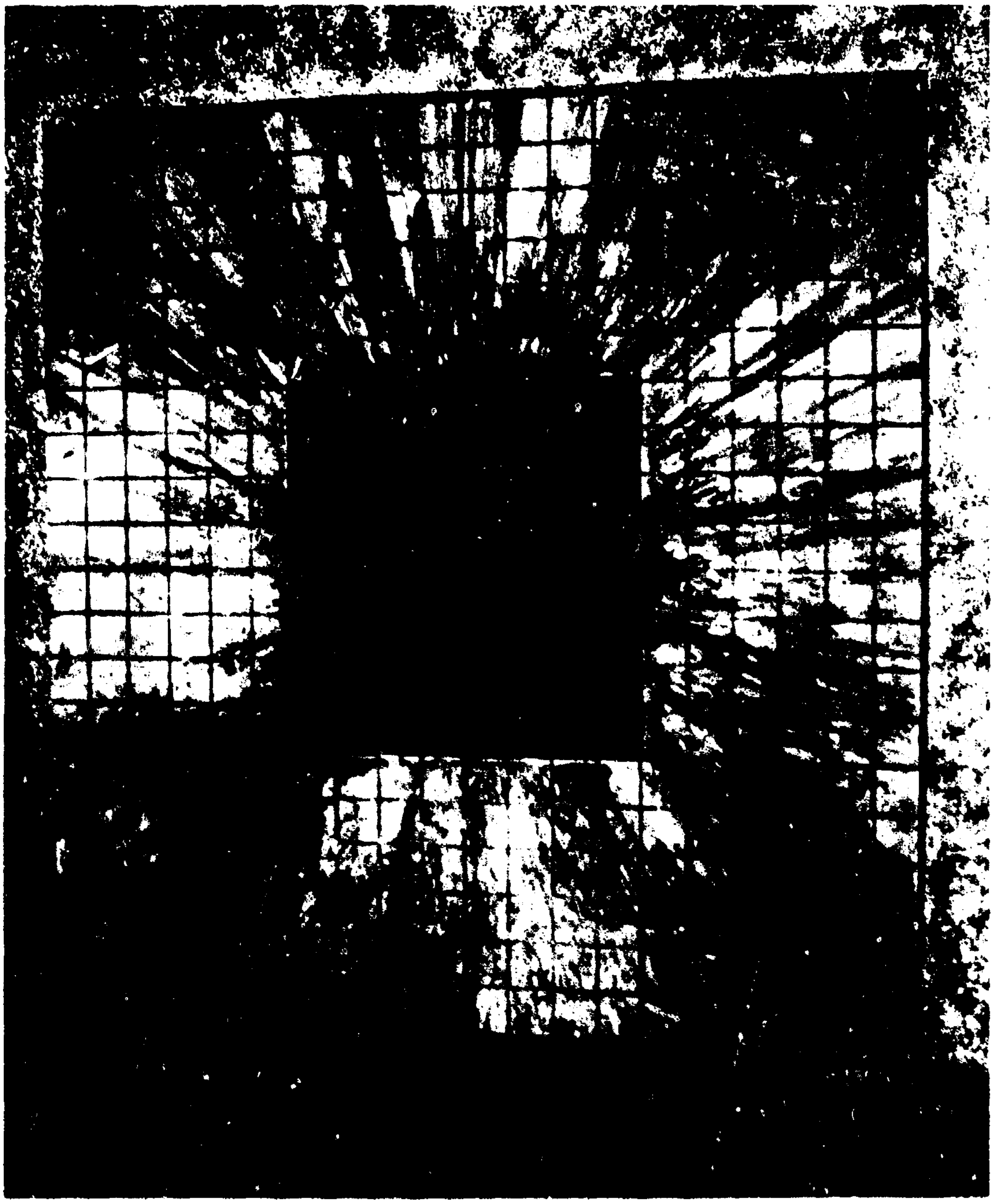


Figure 7.1 DT steel plate and concrete pad at GZ after detonation. (DASA-115-01-TTR-63)

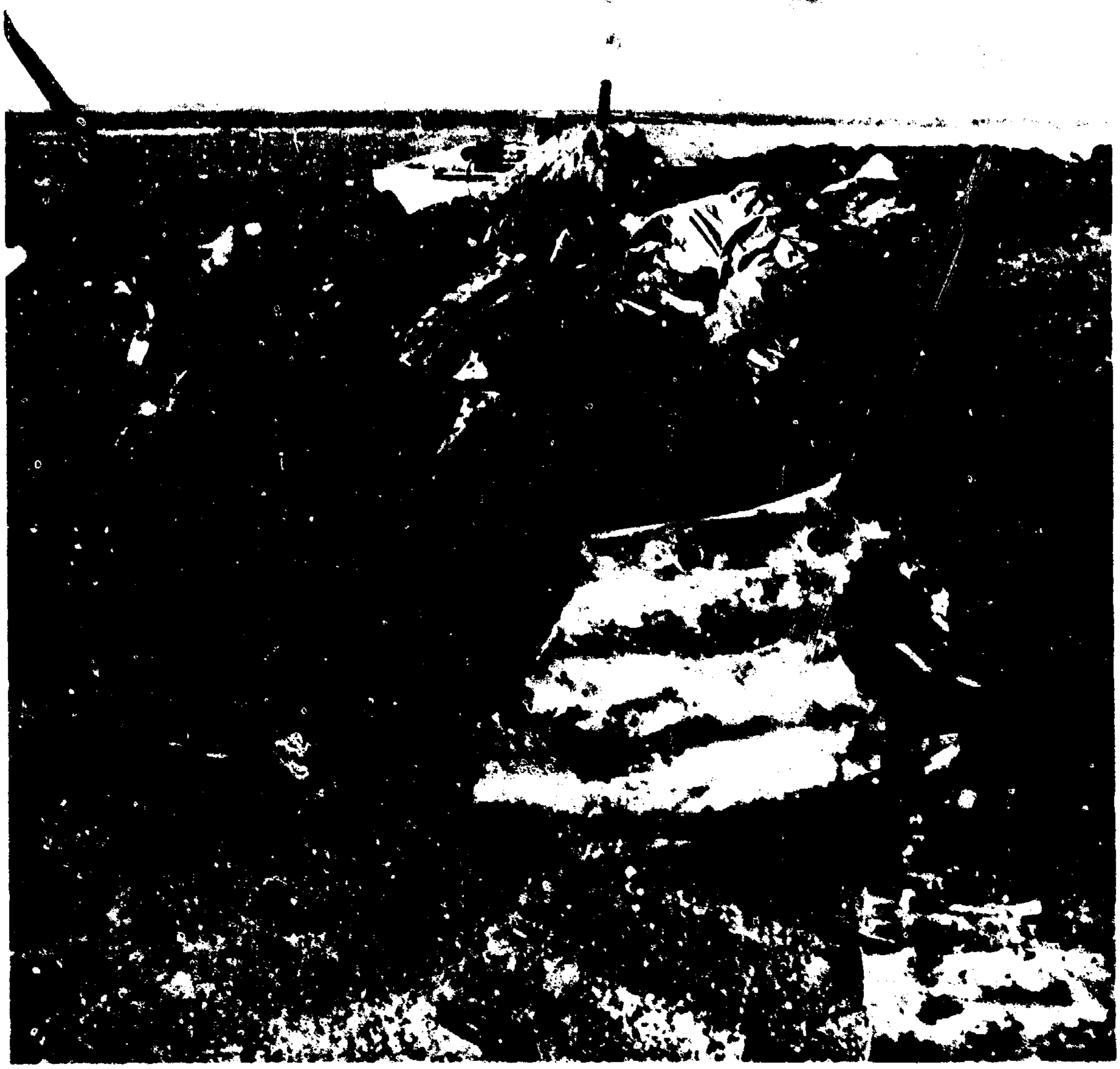


Figure 7.2 Igloo debris as recovered at Tonopah Test Range. (DASA-175-55-TTR-63)

Figure 7.3 Field gamma scanning of igloo debris. (DASA-175-62-TTR-63)

Figure 7.4 Cutting igloo debris for radiochemistry samples. (DASA-176-13-NTS-63)

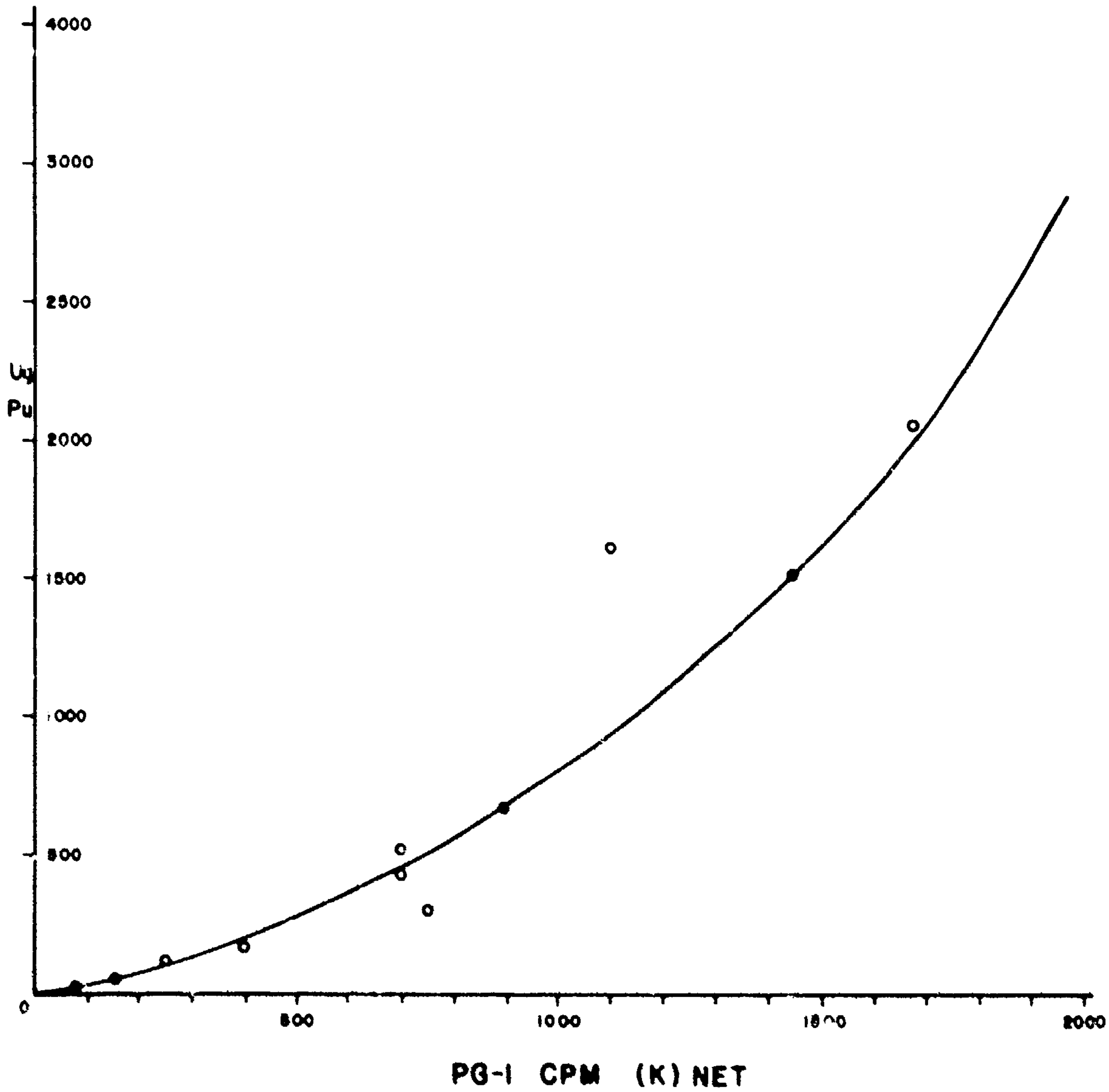


Figure 7.5 PG-1 gamma cpm versus μg Pu^{239} by radiochemistry.

PG-1 - RADIOCHEMISTRY CORRELATION

In order to evaluate the igloo debris from CSII and CSIII, it was necessary to establish conversion factors to convert PG-1 cpm readings to μg. The inherent design of the PG-1 produces a slight non-linearity in readings, and therefore samples of varying degrees of contamination were obtained, readings recorded, and radiochemistry for total plutonium carried out. The results were plotted on a graph, and the following table prepared for rapid conversion of PG-1 cpm to μg of Pu^{239}.

PG-1/PAC-1S cpm (K)	μg Pu^{239}	PG-1/PAC-1S cpm (K)	μg Pu^{239}	PG-1/PAC-1S cpm (K)	μg Pu^{239}
10	6	500	270	1300	1250
20	7	525	285	1325	1290
30	10	550	300	1350	1330
40	12	575	330	1375	1370
50	15	600	350	1400	1425
60	18	625	370	1425	1465
70	20	650	400	1450	1500
80	23	675	430	1475	1550
90	26	700	450	1500	1600
100	28	725	470	1525	1650
110	31	750	500	1550	1700
120	34	775	530	1575	1760
125	35	800	560	1600	1820
130	37	825	580	1625	1880
140	40	850	610	1650	1930
150	42	875	640	1675	1990
160	45	900	670	1700	2050
170	47	925	700	1725	2110
180	50	950	730	1750	2180
190	52	975	740	1775	2250
200	55	1000	800	1800	2330
225	80	1025	835	1825	2400
250	105	1050	870	1850	2480
275	125	1075	910	1875	2550
300	140	1100	940	1900	2640
325	150	1125	975	1925	2730
350	170	1150	1015	1950	2820
375	180	1175	1050	1975	2910
400	200	1200	1090	2000	3000
425	215	1225	1130		
450	230	1250	1170		
475	250	1275	1215		

greater than 2000K - 5000μg (average of 2 off scale numbers)

Figure 7.6 PG-1 gamma cpm versus μg Pu^{238} conversion table.

Figure 7.7 Scanning DT steel plate. (DASA-176-15-NTS-63)

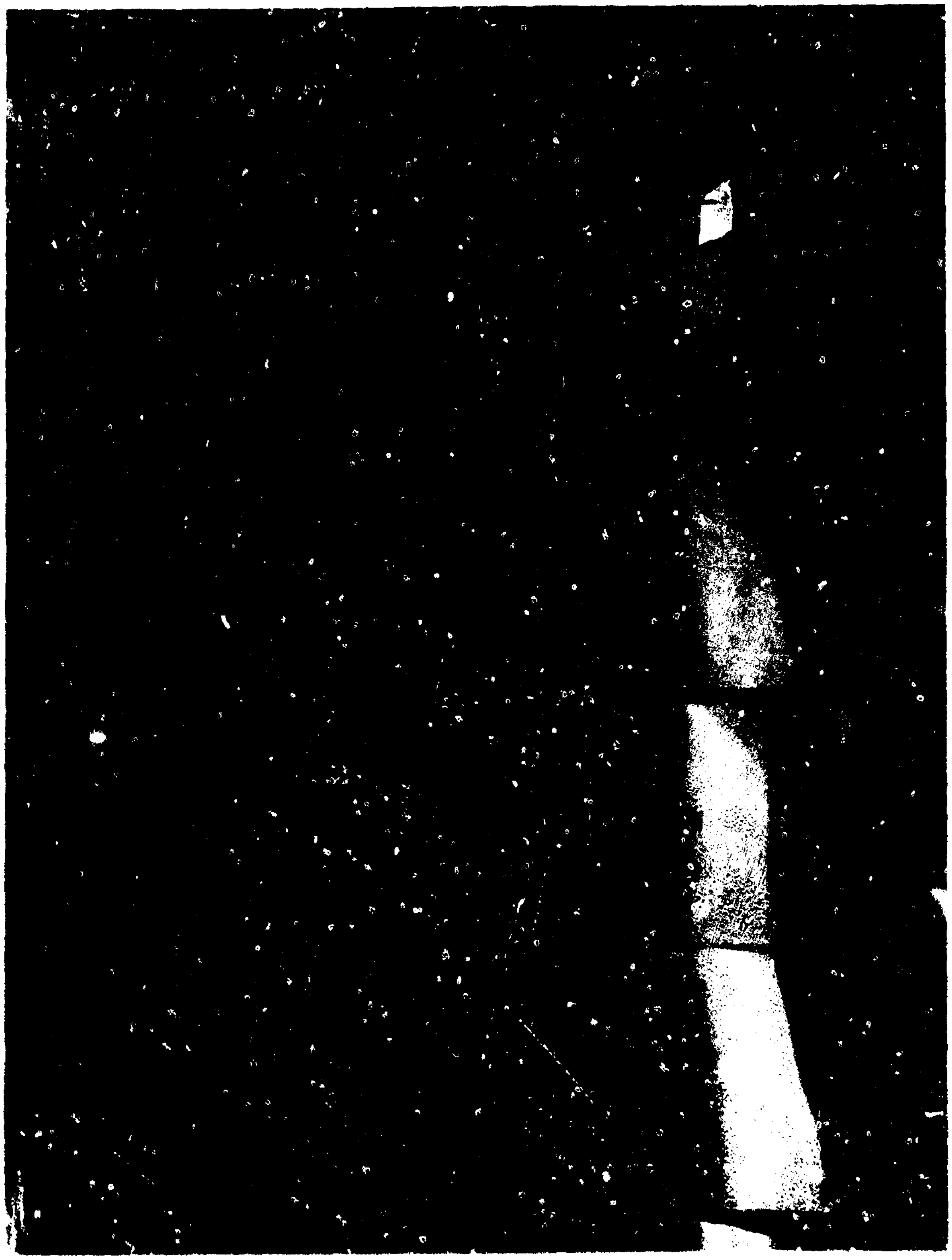


Figure 7.8 X-ray film on DT steel plate. (DASA-175-26-TTR-63)

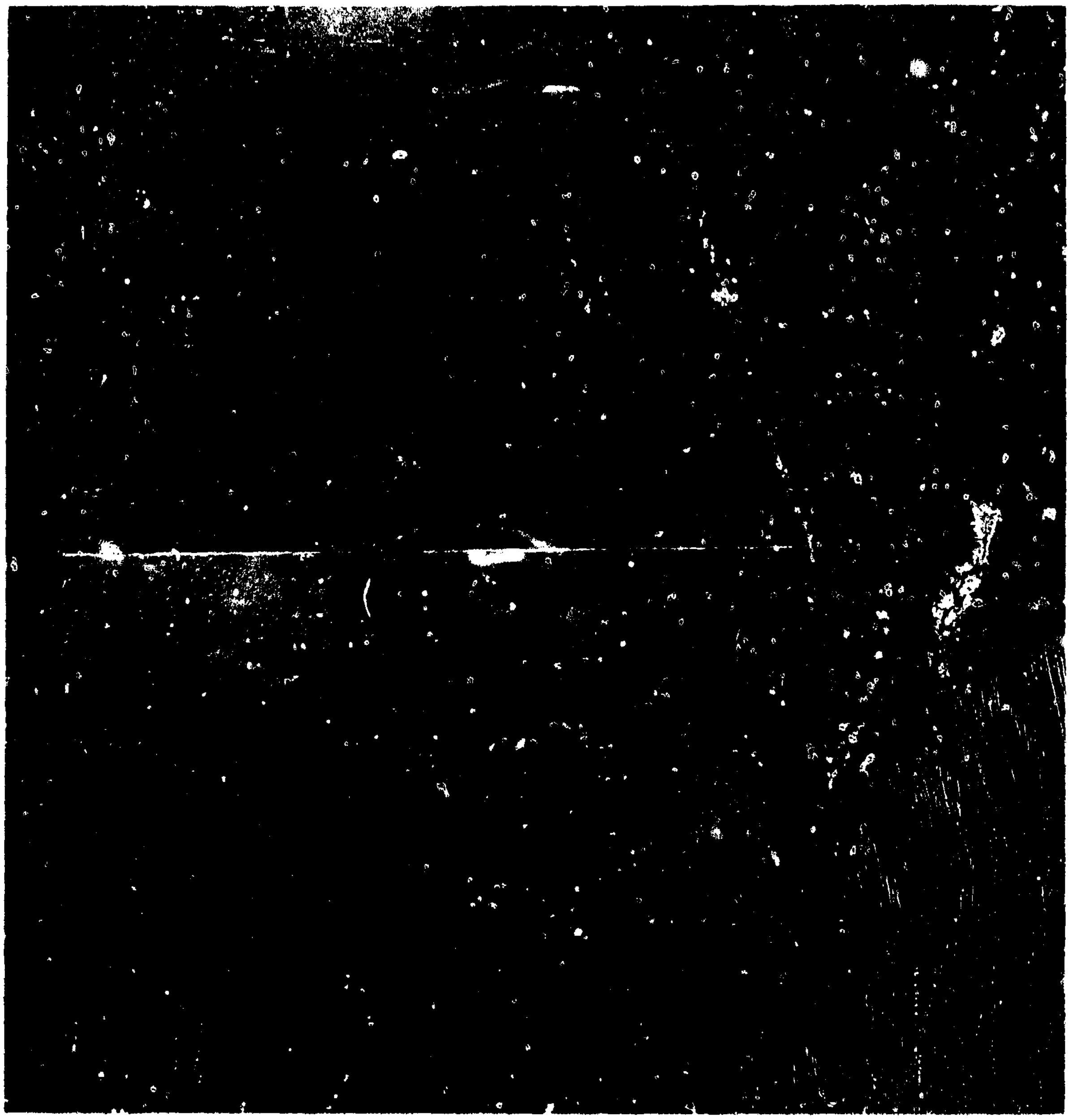


Figure 7.9 Radioautograph of DT steel plate.

Figure 7.10 Dosimetry film on DT steel plate. (DASA-176-11-NTS-63)

Figure 7.11 Radioautograph of CS III igloo debris showing corrugation shadow effect.

ALL READINGS X 1000 NET.
ONLY AM-241 MEASUREMENTS RECORDED.
NUMBER IN ( ) AFTER DECON.

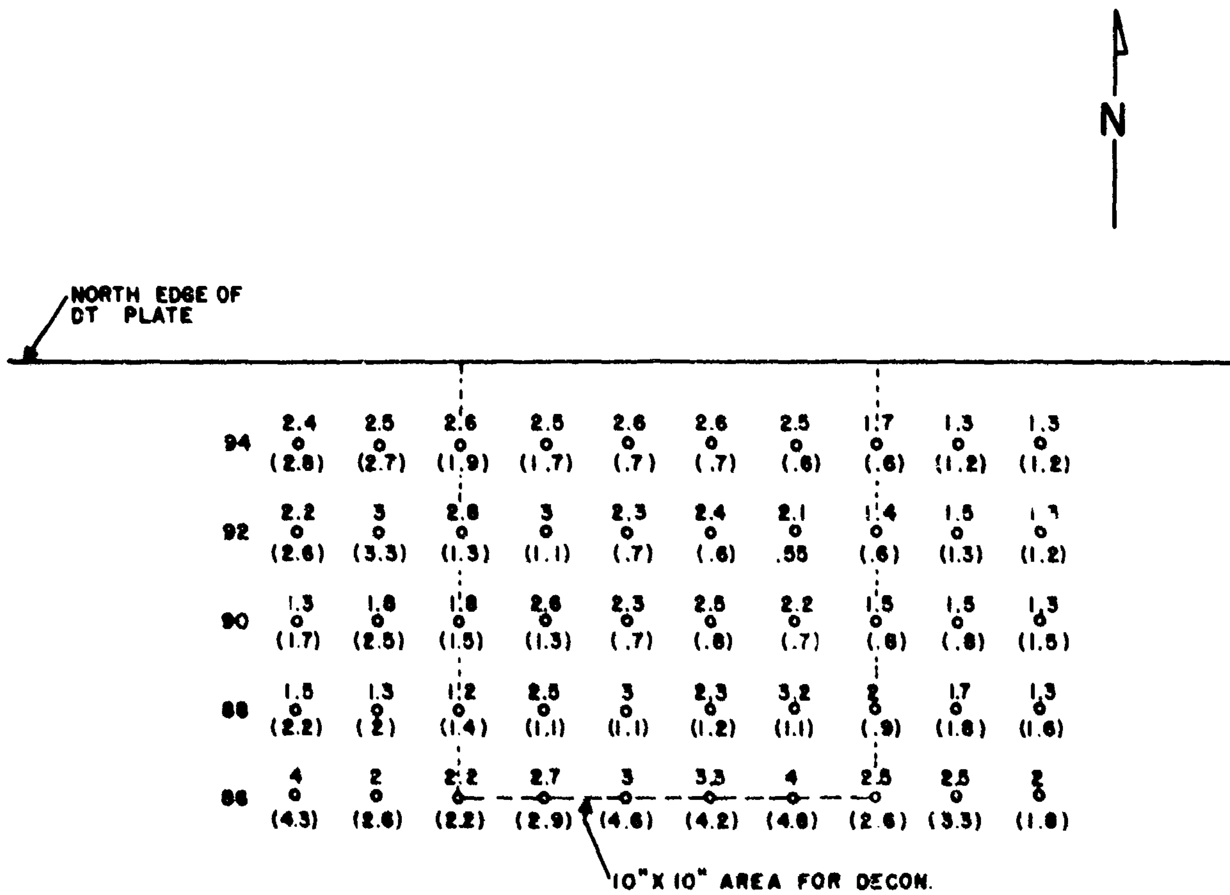


Figure 7.12 Comparison of DT steel plate section before and after decontamination.

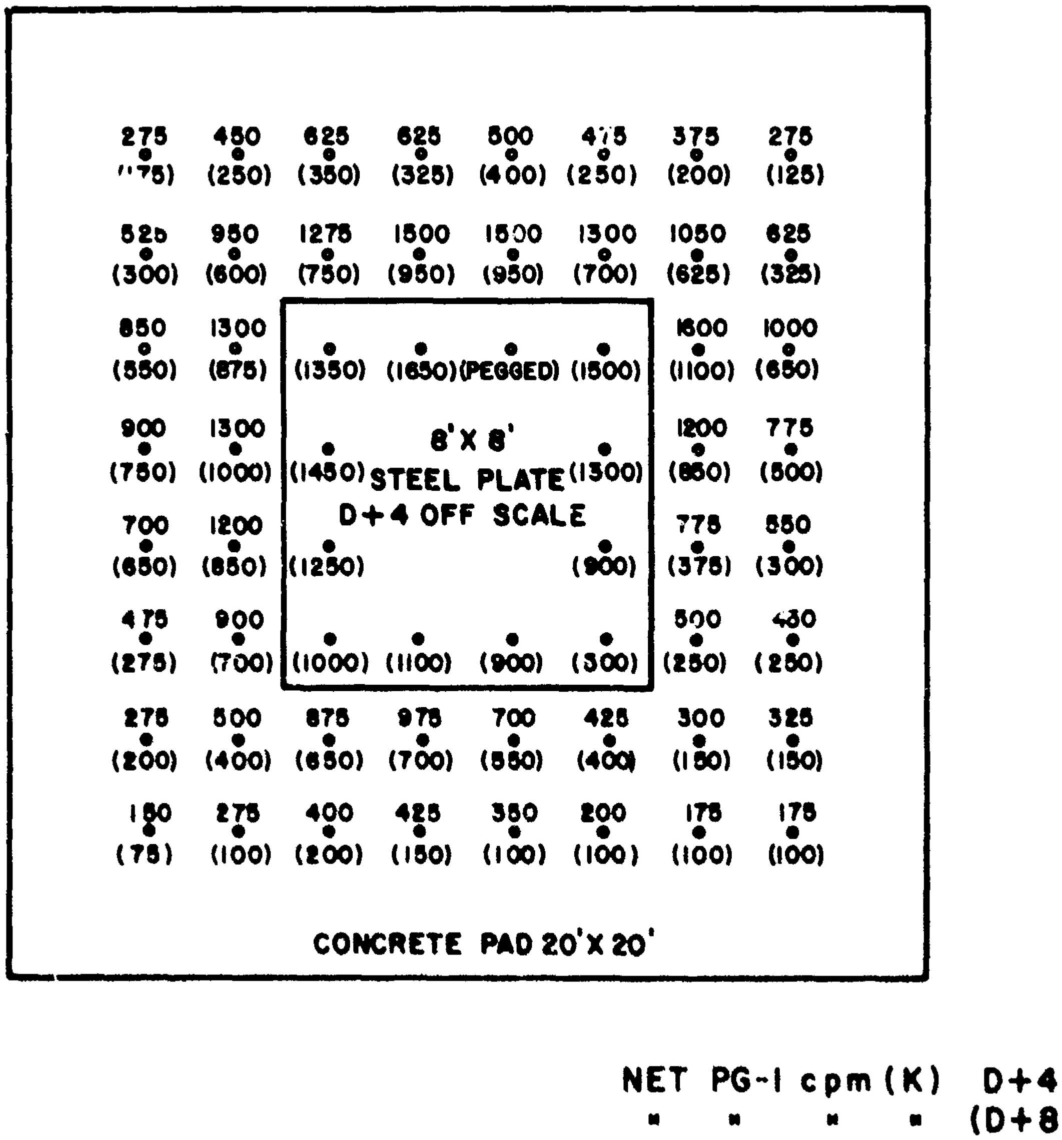


Figure 7.13 Gamma measurements of DT steel plate and concrete pad.

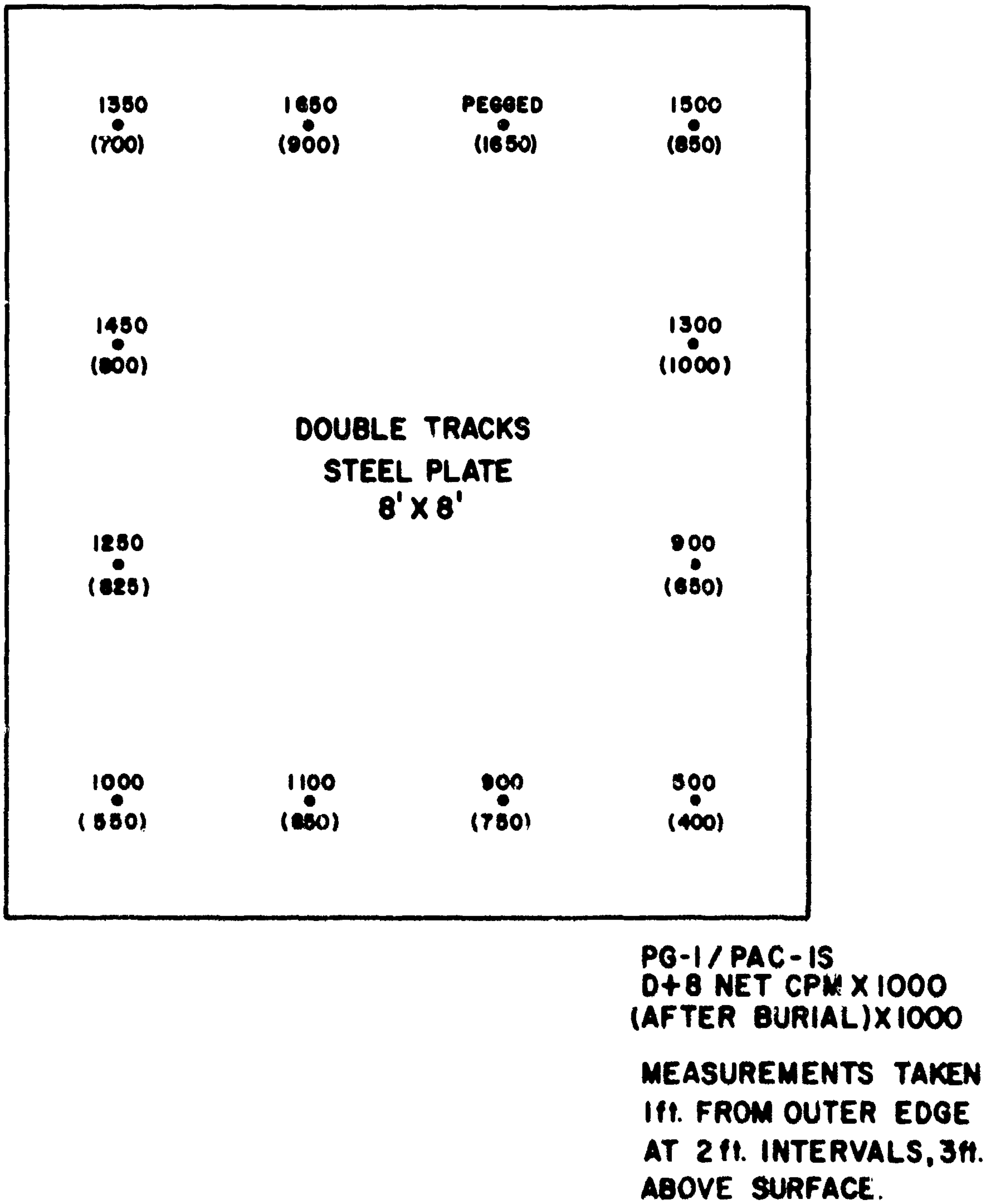


Figure 7.14 Gamma measurements of DT steel plate before and after burial.

Figure 7.15 Photomicrograph showing loose, slag-like oxides.

Figure 7.16 Photomicrograph showing oxides trapped in indentation.

CHAPTER 8

CORRELATION, ACCOUNTABILITY AND DISCUSSION

This chapter is a final resume' and summary of the results and data obtained by Project 2.1, as well as interrelated work by Project 2.5, Project 2.3, the Follow-on work, and other sources. As such, details are purposely omitted, and pertinent information is presented as it relates to each event.

8.1 DOUBLE TRACKS

It was anticipated that Project 2.1 participation in the Double Tracks event would be minimal, consisting mainly of support activities to Project 2.5 in the overall alpha survey. In addition, vehicle-mounted gamma scan and portable gamma survey data were collected in the close-in grid area. The discovery of very high levels of plutonium on the steel plate led to more intensive investigation in the GZ area by all available techniques, and additional measurements were made through the combined resources of Project 2.1 and 2.5. Subsequently, the importance of the scavenging effects of the steel plate was recognized, leading to the Follow-on work.

Alpha survey measurements were made with the PAC-3G as described in Reference 3, and the entire grid survey was completed on D-day. Since an acceptable factor for converting PAC-3G readings to μg equivalents has not been established, it is therefore necessary to outline these data as contours based on cpm/60 cm^2 probe area with the PAC-3G. This applies to all alpha surveys for DT, CS I, II, and III. Figure 6.1 is a contour plot of the A, B, and C grids of the Double Tracks event.

Vehicle-mounted gamma scanner activities initially consisted of defining the hot line peak values and the detectable limits on either side. This was a qualitative exercise, since no quantitative requirements were anticipated or programmed. Figure 6.5 is an outline of the areas defined. An attempt was made to evaluate the steel plate at GZ, but the extremely high levels exceeded the detection equipment capability.

Considerable data was obtained from an area of 100-foot radius to ground zero with portable gamma survey equipment (PG-1/PAC-1SA). This data is shown in Figure 6.9 and was taken on D+4 and D+8. A correlative

ratio of 60:1 for PAC-3G to PG-1 was determined by Project 2.5 (Reference 3).

The concrete pad on Double Tracks was cored on D+1 in locations as shown in Figure 5.2. Analysis of the samples by radiochemistry and extrapolation to the total area of the concrete pad gave an estimate of less than 1 gram of plutonium scavenged by the concrete. Data on which this estimate is based is contained in Table 5.1.

The Follow-on work described in Chapter 7 estimates that a minimum of 92 grams of plutonium was deposited on the steel plate alone. It is believed that this figure is conservative.

8.2 CLEAN SLATE I

Comments pertaining to the A, B, and C grid alpha and gamma surveys of Double Tracks apply as well to CS I. The contour plots in Figures 6.2 and 6.6 show the deposition patterns as determined by these methods.

Experience on Double Tracks prompted a more intensive GZ investigation than was originally anticipated. The vehicle-mounted gamma scanner went into this area on D+1,

and measurements were made over each corner of the CSI concrete pad. These are shown in Figure 6.10, As well, PG-1/PAC-1SA surveys of the concrete pad on D+1 and D+7 resulted in the data shown on the same illustration. It is interesting to note that the levels associated with the CS I concrete pad are far below those found on DT. This might be attributed to the possible quenching effect of the steel plate, which collected and held a large proportion of the plutonium, as well as indicating that concrete does not scavenge as well as metal. The additional high explosive involved probably caused more widespread distribution.

The concrete pad was cored in locations shown in Figure 5.3 on D+2. Radiochemical analysis of these samples and extrapolation to the area of the pad indicated again that less than 1 gram was associated with the concrete pad.

Metal debris samples from device stands were collected and measured by gamma detection techniques. The average deposition was about 245 $\mu g/in^2$ and extrapolated to the total area of the stands, accounted for 2.8 grams of plutonium (Appendix C).

8.3 CLEAN SLATE II

The Clean Slate II event provided the first opportunity for full participation of Project 2.1. Alpha and gamma survey continued on D-Day, much the same as on Double Tracks and CS I. The A grid was eliminated on these events, since the igloo bunker occupied a large portion of this area, making concrete pad placement impractical. The results of alpha survey were plotted as areas encompassed by various cpm/60 cm^2 contours and are shown in Figure 6.3.

The vehicle-mounted gamma scan plot was expressed in hot line determination and detectable limits as shown in Figure 6.7.

As well as the initial gamma scan survey, the vehicle-mounted gamma scanner made concentric surveys around the bunker area from a radius of 55 to 100 feet on D+4. Using correlation techniques established by Project 2.5, (Reference 3), this data was reduced to $\mu g/m^2$. It is estimated that 20.3 grams of plutonium were deposited in the do-nut shaped area. Figure 6.11 is a data sheet for this exercise, showing both net Pu^{239} and AM^{241} read-

ings that were taken. It is pointed out that the Am^{241} data was used to estimate total plutonium in the area, since it is less degraded by soil cover than the Pu^{239}.

The earth mining procedure described in Chapter 2 was carried out, and approximately 203 yd^3 of soil was assayed. It is believed that the soil assayed contained at least 95% of the plutonium associated with the bunker soil. By this technique 23.8 grams of plutonium were accounted for.

Earth coring, while not quantitative, did provide valuable data in support of the mining exercise. The initial data from soil cores indicated that the maximum depth of burial was about 4 inches with a few exceptions where it is believed that sliding earth, after the fallout deposition, may have resulted in deeper burial. Data is contained in Chapter 3.

Concrete coring was accomplished on D+1 and location and data pertaining to these samples are presented in Figure 5.3 and Table 5.1. Metal debris, originally thought to be from the igloo but actually aluminum from device stands, was evaluated both by gamma techniques in the field and radiochemistry in the laboratory. Extrapolation of average values to the total area of the stands indicates

15.7 grams of plutonium was associated with aluminum device stands (Appendix C).

Data from the Follow-on task, described in Chapter 7, indicate that a reasonable estimate of plutonium fixed to debris of the CS II igloo after excavation was approximately 5 grams. It is believed that this estimate is very conservative, based on general observations and conclusions which cannot be supported by experimental data.

8.4 CLEAN SLATE III

Alpha survey and gamma scan exercises on D-day were very similar to CS II, with the A grid again eliminated. The results of alpha survey are shown in Figure 6.4, expressed in PAC-3G cpm/60 cm^2 probe area. Vehicle-mounted gamma scan data were expressed as hot line and detectable limits and are shown as a contour plot in Figure 6.8.

The earth mining procedure used on CS II was repeated on on CS III, assaying 380 yd^3 of bunker soil and accounting for 24.13 grams of plutonium by belt gamma scanner techniques.

Earth coring data confirmed depth distribution measurements made on CS II, with data contained in Chapter 3.

Concrete coring was accomplished on D+1 and location and data pertaining to these samples is presented in Figure 5.5 and Table 5.1.

Metal debris, again aluminum, when extrapolated to the total stand area contained 17.1 grams of plutonium (Appendix C).

Data from the Follow-on work for the CS III igloo debris indicates approximately 21.2 grams associated with this debris. Again this is believed to be a very conservative estimate when compared to probable original deposition levels. It is believed that data obtained from CS III debris has more confidence than that obtained from CS II.

CHAPTER 9

CONCLUSIONS

Because contaminant deposition patterns in the immediate vicinity of non-nuclear detonations of Pu-bearing weapons are highly irregular, rather unorthodox detection techniques are required. Alpha monitoring is of no real value beyond establishing the fact that dispersal of the contaminant has or has not occurred. Between this determination and the requirements of final area cleanup, low-energy gamma detection techniques are more applicable. Actually, complete reliance on alpha measurements will lead to erroneous conclusions in highly contaminated areas. It is to be emphasized that all such measurements should be preceded by a special gamma survey to determine the presence or absence of a fission product radiation field of penetrating energies.

Project 2.1 was concerned primarily with evaluating the scavenging effect of the different debris material scattered by Roller Coaster detonations. Both aluminun and galvanized iron sections were found to be highly contaminated. Concrete was not an effective scavenger, indicating

storage facilities should avoid this material as a structural component. The igloos used in Roller Coaster do not optimize the parameters of material and design. Neither do operational results provide a singular route to the best answer. Various laboratory experiments can be devised to provide an insight into the best solution. No significant improvement in local Pu scavenging was observed with eight feet of earth overburden when compared to two feet of overburden. Considering the summation of all debris accountability, a surprisingly low percentage (less than 20%) of the plutonium was found in the immediate vicinity of GZ.

The capability of collecting and assaying contaminated debris has been greatly enhanced by the special instrumentation built for and evaluated during Roller Coaster. A vehicle-mounted gamma scanner is very useful for rapid fallout delineation and to supplement other equipment on special studies.

The U. S. Army Chemical Corps Mask, Model M-17, was found to provide satisfactory respiratory protection for project personnel without the usual problem of personal discomfort. Its speech transmission characteristics were tested severely by Roller Coaster requirements without any serious defects observed.

APPENDIX A

Appendix A is a compilation of soil core scanning data obtained after return from the Roller Coaster site. Core scanning was repeated at the Eberline Instrument Corporation plant in Santa Fe, New Mexico, since some questions had been raised concerning the validity of a few points in the field.

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 1

CORE LENGTH (INCHES) 30

BACKGROUND (cpm) 103 Am^{241} 127 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	66	62
2	1/2	62	81
3	1/2	52	51
4	1/2	37	25
1	3	55	39
2	3	63	45
3	3	73	59
4	3	57	68

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 2

CORE LENGTH (INCHES)

BACKGROUND (cpm) 122 Am^{241} 167 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	133	149
2	1/2	141	155
3	1/2	149	190
4	1/2	124	174
1	2 1/2	160	196
2	2 1/2	197	341
3	2 1/2	226	342
4	2 1/2	252	310
1	4 1/2	103	67
2	4 1/2	108	78
3	4 1/2	102	83
4	4 1/2	95	60

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 3

CORE LENGTH (INCHES)

BACKGROUND (cpm) 103 Am^{241} 127 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	84	112
2	1/2	54	29
3	1/2	50	30
4	1/2	71	90
1	3	75	117
2	3	65	82
3	3	62	32
4	3	70	63
1	5 1/2	40	24
2	5 1/2	48	34
3	5 1/2	60	48
4	5 1/2	63	43

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 7

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 95 Am^{241} 111 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	1076	815
2	1/2	1446	2195
3	1/2	1360	1222
4	1/2	1117	809
1	2 1/2	248	156
2	2 1/2	329	544
3	2 1/2	181	221
4	2 1/2	199	107
1	4 1/2	83	90
2	4 1/2	119	205
3	4 1/2	107	183
4	4 1/2	107	241

SOIL CORE EVALUATION DATA

CLEAN SLATE II **EVENT** **DATE**

CORE NO. 8 or 18

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 105 Am^{241} 159 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	65	74
2	1/2	89	98
3	1/2	72	131
4	1/2	89	142

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 9

CORE LENGTH (INCHES) 30

BACKGROUND (cpm) 105 Am^{241} 159 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	37	72
2	1/2	31	48
3	1/2	41	75
4	1/2	29	121
1	2 1/2	419	387
2	2 1/2	368	376
3	2 1/2	311	370
4	2 1/2	419	443
1	4 1/2	253	185
2	4 1/2	218	190
3	4 1/2	225	104
4	4 1/2	253	204

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 9

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 103 Am^{241} 226 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	1285	773
2	1/2	1841	758
3	1/2	1400	713
4	1/2	1562	1152
1	2 1/2	368	217
2	2 1/2	380	329
3	2 1/2	300	91
4	2 1/2	228	53
1	4 1/2	101	83
2	4 1/2	130	155
3	4 1/2	106	2
4	4 1/2	130	48

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 10

CORE LENGTH (INCHES) 48

BACKGROUND (cpm) 123 Am^{241} 158 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	1576	860
2	1/2	1977	958
3	1/2	1503	509
4	1/2	1452	735
1	2 1/2	897	561
2	2 1/2	491	312
3	2 1/2	552	421
4	2 1/2	534	386
1	4 1/2	98	305
2	4 1/2	106	150
3	4 1/2	114	130
4	4 1/2	116	123

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 5

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 115 Am^{241} 131 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	638	715
2	1/2	996	1070
3	1/2	1009	1442
4	1/2	735	751
1	2 1/2	340	396
2	2 1/2	317	566
3	2 1/2	356	582
4	2 1/2		
1	4 1/2		
2	4 1/2		
3	4 1/2		
4	4 1/2		

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 11

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 121 Am^{241} 149 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	31	42
2	1/2	42	54
3	1/2	55	60
4	1/2	34	48
1	2 1/2	94	86
2	2 1/2	82	74
3	2 1/2	111	107
4	2 1/2	66	99
1	4 1/2	108	97
2	4 1/2	94	90
3	4 1/2	108	116
4	4 1/2	61	58

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 12

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 122 Am^{241} 164 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	452	470
2	1/2	422	531
3	1/2	311	403
4	1/2	320	303
1	2 1/2	81	52
2	2 1/2	88	101
3	2 1/2	76	69
4	2 1/2	128	86
1	4 1/2	109	91
2	4 1/2	98	90
3	4 1/2	102	78
4	4 1/2	119	81

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 13

CORE LENGTH (INCHES)

BACKGROUND (cpm) 94 Am^{241} 132 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	465	468
2	1/2	319	352
3	1/2	401	385
4	1/2	410	394
1	2 1/2	48	35
2	2 1/2	54	47
3	2 1/2	70	82
4	2 1/2	60	73
1	4 1/2	43	14
2	4 1/2	44	41
3	4 1/2	67	58
4	4 1/2	51	39

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 14

CORE LENGTH (INCHES)

BACKGROUND (cpm) 99 Am^{241} 112 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	1337	1107
2	1/2	1347	934
3	1/2	1521	933
4	1/2	1369	936
1	2 1/2	338	325
2	2 1/2	286	527
3	2 1/2	304	341
4	2 1/2	296	291
1	4 1/2	300	363
2	4 1/2	251	421
3	4 1/2	248	192
4	4 1/2	250	270

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 15

CORE LENGTH (INCHES) 30

BACKGROUND (cpm) 118 Am^{241} 178 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	208	468
2	1/2	248	426
3	1/2	281	338
4	1/2	269	368
1	2 1/2	93	86
2	2 1/2	91	48
3	2 1/2	90	31
4	2 1/2	118	184
1	4 1/2	70	21
2	4 1/2	52	1
3	4 1/2	75	52
4	4 1/2	59	17

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 16

CORE LENGTH (INCHES)

BACKGROUND (cpm) 97 Am^{241} 137 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	4356	5216
2	1/2	4253	4471
3	1/2	4110	4036
4	1/2	6230	11329
1	2 1/2	1750	1944
2	2 1/2	1712	2297
3	2 1/2	3208	7703
4	2 1/2	2542	7412
1	4 1/2	425	1046
2	4 1/2	265	205
3	4 1/2	1001	3156
4	4 1/2	1238	4935
1	6 1/2	188	305
2	6 1/2	143	143
3	6 1/2	205	617
4	6 1/2	155	237
1	8 1/2	119	79
2	8 1/2	94	84
3	8 1/2	94	101
4	8 1/2	109	103

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 18

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 119 Am^{241} 199 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	261	281
2	1/2	280	243
3	1/2	148	142
4	1/2	202	139
1	2 1/2	87	53
2	2 1/2	86	127
3	2 1/2	106	110
4	2 1/2	79	59
1	4 1/2	98	106
2	4 1/2	84	105
3	4 1/2	106	100
4	4 1/2	91	82

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 19

CORE LENGTH (INCHES)

BACKGROUND (cpm) 125 Am^{241} 166 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	81	67
2	1/2	58	57
3	1/2	97	88
4	1/2	56	50
1	2 1/2	94	76
2	2 1/2	69	56
3	2 1/2	89	94
4	2 1/2	96	48
1	4 1/2	98	89
2	4 1/2	102	62
3	4 1/2	87	81
4	4 1/2	83	63

SOIL CORE EVALUATION DATA

CLEAN SLATE II **EVENT** **DATE**

CORE NO. 21

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 118 Am^{241} 157 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	951	1466
2	1/2	799	809
3	1/2	622	703
4	1/2	719	840
1	2 1/2	166	184
2	2 1/2	315	711
3	2 1/2	300	502
4	2 1/2	185	161
1	4 1/2	95	93
2	4 1/2	116	125
3	4 1/2	114	139
4	4 1/2	99	121

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 23

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 138 Am^{241} 168 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	2651	1327
2	1/2	1947	1568
3	1/2	2390	1891
4	1/2	3330	1444
1	2 1/2	2521	727
2	2 1/2	2577	743
3	2 1/2	4406	1325
4	2 1/2	3787	1262
1	4 1/2	783	837
2	4 1/2	644	519
3	4 1/2	483	306
4	4 1/2	707	991

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 27

CORE LENGTH (INCHES)

BACKGROUND (cpm) 146 Am^{241} 164 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	4088	2229
2	1/2	7296	6095
3	1/2	12585	12061
4	1/2	9583	6585
1	2 1/2	12294	579
2	2 1/2	3651	6741
3	2 1/2	4514	8892
4	2 1/2	2082	2421
1	4 1/2	152	151
2	4 1/2	358	647
3	4 1/2	286	664
4	4 1/2	206	259

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 29

CORE LENGTH (INCHES) 48

BACKGROUND (cpm) 124 Am^{241} 152 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	141	106
2	1/2	145	79
3	1/2	109	94
4	1/2	146	116
1	2 1/2	152	286
2	2 1/2	158	272
3	2 1/2	123	103
4	2 1/2	148	187
1	4 1/2	129	124
2	4 1/2	102	78
3	4 1/2	117	107
4	4 1/2	127	116

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 33

CORE LENGTH (INCHES)

BACKGROUND (cpm) 142 Am^{241} 178 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	330	665
2	1/2	329	559
3	1/2	413	973
4	1/2	470	1081
1	2 1/2	1901	1702
2	2 1/2	2106	1373
3	2 1/2	2125	1618
4	2 1/2	1946	1617
1	4 1/2	660	267
2	4 1/2	1123	1341
3	4 1/2	2043	4123
4	4 1/2	1082	1830
1	6 1/2	247	131
2	6 1/2	95	106
3	6 1/2	177	297
4	6 1/2	326	293
1	8 1/2	89	72
2	8 1/2	43	13
3	8 1/2	138	301
4	8 1/2	93	144

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 30

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 98 Am^{241} 126 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	338	317
2	1/2	542	798
3	1/2	472	499
4	1/2	531	762
1	2 1/2	120	146
2	2 1/2	114	106
3	2 1/2	65	70
4	2 1/2	67	54
1	4 1/2	54	45
2	4 1/2	55	48
3	4 1/2	36	48
4	4 1/2	52	36

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. [illegible]2

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 97 Am^{241} 141 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	13218	6854
2	1/2	13326	5843
3	1/2	11022	4015
4	1/2	14001	5835
1	2 1/2	12338	6323
2	2 1/2	16156	10562
3	2 1/2	16873	6944
4	2 1/2	13540	6702
1	2 1/2	612	301
2	2 1/2	925	1323
3	2 1/2	1240	2171
4	4 1/2	503	241
1	6 1/2	170	244
2	6 1/2	172	415
3	6 1/2	191	460
4	6 1/2	117	227

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 31

CORE LENGTH (INCHES)

BACKGROUND (cpm) 99 Am^{241} 142 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	2451	1408
2	1/2	1958	1145
3	1/2	2824	1967
4	1/2	2583	2185
1	2 1/2	1434	1031
2	2 1/2	2584	1258
3	2 1/2	2409	2808
4	2 1/2	1768	1354
1	4 1/2	135	194
2	4 1/2	215	14
3	4 1/2	156	389
4	4 1/2	196	371

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 32

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 98 Am^{241} 140 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	452	128
2	1/2	427	104
3	1/2	532	228
4	1/2	497	225
1	2 1/2	173	31
2	2 1/2	348	199
3	2 1/2	365	244
4	2 1/2	217	65
1	4 1/2	16	0
2	4 1/2	42	28
3	4 1/2	30	55
4	4 1/2	14	0

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 34

CORE LENGTH (INCHES)

BACKGROUND (cpm) 73 Am^{241} 95 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	359	132
2	1/2	453	372
3	1/2	1023	1988
4	1/2	579	306
1	2 1/2	10676	2780
2	2 1/2	14850	3931
3	2 1/2	27707	11169
4	2 1/2	10360	3097
1	4 1/2	7197	2667
2	4 1/2	9477	5315
3	4 1/2	18310	4524
4	4 1/2	6367	2350
1	6 1/2	594	677
2	6 1/2	849	1481
3	6 1/2	724	1210
4	6 1/2	549	453
1	8 1/2	198	697
2	8 1/2	198	550
3	8 1/2	161	448
4	8 1/2	117	187

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 36

CORE LENGTH (INCHES) 30

BACKGROUND (cpm) 85 Am^{241} 119 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	554	245
2	1/2	611	509
3	1/2	558	286
4	1/2	611	309
1	2 1/2	1898	1249
2	2 1/2	1613	793
3	2 1/2	1869	901
4	2 1/2	2249	1260
1	4 1/2	191	229
2	4 1/2	123	186
3	4 1/2	262	214
4	4 1/2	333	639

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 38

CORE LENGTH (INCHES)

BACKGROUND (cpm) 96 Am^{241} 124 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	1703	1540
2	1/2	751	1000
3	1/2	1096	847
4	1/2	2638	2720
1	2 1/2	452	1059
2	2 1/2	233	250
3	2 1/2	308	424
4	2 1/2	451	1003
1	4 1/2	74	85
2	4 1/2	78	124
3	4 1/2	88	166
4	4 1/2	103	235
1	6 1/2	63	76
2	6 1/2	83	88
3	6 1/2	66	107
4	6 1/2	73	74

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 39

CORE LENGTH (INCHES) 30

BACKGROUND (cpm) 98 Am^{241} 117 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	1352	1295
2	1/2	1420	1787
3	1/2	938	838
4	1/2	1120	686
1	2 1/2	82	93
2	2 1/2	128	252
3	2 1/2	91	96
4	2 1/2	62	65
1	4 1/2	91	69
2	4 1/2	107	102
3	4 1/2	87	146
4	4 1/2	84	80

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 41

CORE LENGTH (INCHES) 30

BACKGROUND (cpm) 109 Am^{241} 142 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	1133	654
2	1/2	1360	903
3	1/2	1385	1009
4	1/2	1227	897
1	2 1/2	3068	7366
2	2 1/2	3768	7829
3	2 1/2	2810	4252
4	2 1/2	2676	6397
1	4 1/2	686	1603
2	4 1/2	444	833
3	4 1/2	879	1498
4	4 1/2	592	1761
1	6 1/2	178	322
2	6 1/2	173	291
3	6 1/2	235	409
4	6 1/2	149	312

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 42

CORE LENGTH (INCHES)

BACKGROUND (cpm) 104 Am^{241} 142 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	3258	3252
2	1/2	3516	4870
3	1/2	2939	4098
4	1/2	2731	3489
1	2 1/2	3198	3386
2	2 1/2	2590	2131
3	2 1/2	1938	2425
4	2 1/2	2957	3256
1	4 1/2	502	688
2	4 1/2	473	1023
3	4 1/2	465	1009
4	4 1/2	388	736
1	6 1/2	157	208
2	6 1/2	150	240
3	6 1/2	130	226
4	6 1/2	135	164

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 43

CORE LENGTH (INCHES) 30

BACKGROUND (cpm) 128 Am^{241} 146 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	1116	607
2	1/2	935	443
3	1/2	1035	541
4	1/2	1218	675
1	2 1/2	882	218
2	2 1/2	1351	1127
3	2 1/2	1418	987
4	2 1/2	319	379

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 44

CORE LENGTH (INCHES)

BACKGROUND (cpm) 131 Am^{241} 182 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	20311	8917
2	1/2	17333	6478
3	1/2	19596	5654
4	1/2	24148	8377
1	2 1/2	7785	7591
2	2 1/2	6446	3912
3	2 1/2	5838	4720
4	2 1/2	5406	2873
1	2 1/2	726	1201
2	4 1/2	936	2118
3	4 1/2	362	356
4	4 1/2	46[illegible]	518
1	6 1/2	153	176
2	6 1/2	150	192
3	6 1/2	121	104
4	6 1/2	135	405

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 45

CORE LENGTH (INCHES) 48

BACKGROUND (cpm) 123 Am^{241} 171 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	3924	4912
2	1/2	7405	7029
3	1/2	9236	8450
4	1/2	4679	2960
1	2 1/2	339	264
2	2 1/2	437	848
3	2 1/2	427	951
4	2 1/2	349	615
1	4 1/2	134	142
2	4 1/2	92	219
3	4 1/2	112	224
4	4 1/2	108	99

SOIL CORE EVALUATION DATA

CLEAN SLATE II EVENT DATE

CORE NO. 46

CORE LENGTH (INCHES)

BACKGROUND (cpm) 137 Am^{241} 176 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	3738	5523
2	1/2	2506	2311
3	1/2	2142	2248
4	1/2	3266	5236
1	2 1/2	2575	8286
2	2 1/2	1138	2319
3	2 1/2	517	378
4	2 1/2	1213	2444
1	4 1/2	172	372
2	4 1/2	276	505
3	4 1/2	159	512
4	4 1/2	140	129
1	6 1/2	78	142
2	6 1/2	112	223
3	6 1/2	72	98
4	6 1/2	91	136

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 1

CORE LENGTH (INCHES)

BACKGROUND (cpm) 131 Am^{241} 195 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	627	317
2	1/2	750	323
3	1/2	851	364
4	1/2	896	560
1	2 1/2	2620	1316
2	2 1/2	2727	1385
3	2 1/2	2349	1102
4	2 1/2	1995	735
1	4 1/2	216	192
2	4 1/2	147	127
3	4 1/2	159	128
4	4 1/2	187	128
1	6 1/2	59	20
2	6 1/2	85	54
3	6 1/2	100	52
4	6 1/2	69	30

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 1-A

CORE LENGTH (INCHES)

BACKGROUND (cpm) 108 Am^{241} 150 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	470	540
2	1/2	379	244
3	1/2	630	490
4	1/2	617	503
1	2 1/2	335	420
2	2 1/2	211	243
3	2 1/2	283	277
4	2 1/2	314	404
1	4 1/2	179	217
2	4 1/2	106	105
3	4 1/2	126	155
4	4 1/2	176	223

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 1-B

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 118 Am^{241} 162 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	198	104
2	1/2	232	164
3	1/2	126	81
4	1/2	247	146
1	2 1/2	396	505
2	2 1/2	323	539
3	2 1/2	494	533
4	2 1/2	376	678
1	4 1/2	154	247
2	4 1/2	112	126
3	4 1/2	163	179
4	4 1/2	133	147

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 2

CORE LENGTH (INCHES) 48

BACKGROUND (cpm) 122 Am^{241} 180 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	564	225
2	1/2	577	149
3	1/2	600	147
4	1/2	581	200
1	2 1/2	1633	823
2	2 1/2	777	250
3	2 1/2	1030	681
4	2 1/2	1330	776
1	4 1/2	100	110
2	4 1/2	88	59
3	4 1/2	117	128
4	4 1/2	119	142
1	6 1/2	109	83
2	6 1/2	74	60
3	6 1/2	104	123
4	6 1/2	103	64

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 2-A

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 109 Am^{241} 133 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	352	668
2	1/2	332	858
3	1/2	307	836
4	1/2	363	903
1	2 1/2	1069	884
2	2 1/2	1058	986
3	2 1/2	953	1171
4	2 1/2	1489	2426
1	4 1/2	1324	984
2	4 1/2	1090	730
3	4 1/2	1081	814
4	4 1/2	1156	861
1	6 1/2	1607	1198
2	6 1/2	805	372
3	6 1/2	1161	1574
4	6 1/2	789	1070
1	8 1/2	1125	1135
2	8 1/2	661	328
3	8 1/2	781	560
4	1/2	1127	1130

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 2-B

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 104 Am^{241} 137 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	872	555
2	1/2	802	351
3	1/2	737	364
4	1/2	751	346
1	2 1/2	756	520
2	2 1/2	672	389
3	2 1/2	686	371
4	2 1/2	530	271
1	4 1/2	132	157
2	4 1/2	127	218
3	4 1/2	125	167
4	4 1/2	121	145

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 3

CORE LENGTH (INCHES) 48

BACKGROUND (cpm) 132 Am^{241} 154 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	393	223
2	1/2	368	266
3	1/2	259	148
4	1/2	308	153
1	2 1/2	551	388
2	2 1/2	463	448
3	2 1/2	285	232
4	2 1/2	524	316
1	4 1/2	72	121
2	4 1/2	109	194
3	4 1/2	107	148
4	4 1/2	128	148

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 3-A

CORE LENGTH (INCHES)

BACKGROUND (cpm) 120 Am^{241} 175 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	719	567
2	1/2	950	758
3	1/2	863	657
4	1/2	668	636
1	2 1/2	326	274
2	2 1/2	415	421
3	2 1/2	298	206
4	2 1/2	282	257
1	4 1/2	194	258
2	4 1/2	158	583
3	4 1/2	131	142
4	2 1/2	116	136

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 3-B

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 145 Am^{241} 173 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	581	189
2	1/2	651	300
3	1/2	527	244
4	1/2	503	186
1	2 1/2	949	456
2	2 1/2	886	517
3	2 1/2	870	584
4	2 1/2	955	554
1	4 1/2	208	219
2	4 1/2	308	418
3	4 1/2	257	220
4	4 1/2	244	284

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 4

CORE LENGTH (INCHES) 48

BACKGROUND (cpm) 88 Am^{241} 138 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	509	307
2	1/2	482	215
3	1/2	479	413
4	1/2	455	164
1	2 1/2	110	45
2	2 1/2	119	113
3	2 1/2	159	182
4	2 1/2	103	99
1	4 1/2	57	72
2	4 1/2	80	80
3	4 1/2	52	38
4	4 1/2	43	25

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 4-A

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 85 Am^{241} 128 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	148	317
2	1/2	201	224
3	1/2	96	163
4	1/2	287	327
1	2 1/2	995	663
2	2 1/2	1175	838
3	2 1/2	1038	608
4	2 1/2	1076	632
1	4 1/2	1436	581
2	4 1/2	1555	690
3	4 1/2	1259	622
4	4 1/2	1314	545
1	6 1/2	171	109
2	6 1/2	169	89
3	6 1/2	185	305
4	6 1/2	223	385

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 4-B

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 100 Am^{241} 144 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	195	89
2	1/2	189	123
3	1/2	235	167
4	1/2	205	99
1	2 1/2	249	143
2	2 1/2	276	113
3	2 1/2	191	66
4	2 1/2	210	75
1	4 1/2	57	47
2	4 1/2	68	57
3	4 1/2	88	58
4	4 1/2	97	89

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 5

CORE LENGTH (INCHES) 48

BACKGROUND (cpm) 103 Am^{241} 148 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	313	265
2	1/2	196	152
3	1/2	112	50
4	1/2	187	136
1	2 1/2	185	177
2	2 1/2	182	272
3	2 1/2	226	203
4	2 1/2	165	159
1	4 1/2	209	309
2	4 1/2	185	286
3	4 1/2	207	160
4	4 1/2	217	329
1	6 1/2	82	94
2	6 1/2	110	165
3	6 1/2	104	112
4	6 1/2	123	216

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 5-A

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 123 Am^{241} 136 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	264	234
2	1/2	241	316
3	1/2	186	224
4	1/2	208	200
1	2 1/2	721	424
2	2 1/2	902	459
3	2 1/2	997	431
4	2 1/2	753	367
1	4 1/2	751	386
2	4 1/2	955	548
3	4 1/2	998	388
4	4 1/2	699	391
1	6 1/2	327	148
2	6 1/2	273	105
3	6 1/2	394	234
4	6 1/2	609	524
1	8 1/2	8[illegible]	97
2	8 1/2	121	109
3	8 1/2	105	100
4	8 1/2	101	110

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 5-B

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 120 Am^{241} 182 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	342	83
2	1/2	340	67
3	1/2	473	77
4	1/2	379	48
1	2 1/2	463	232
2	2 1/2	1215	517
3	2 1/2	685	242
4	2 1/2	396	342
1	4 1/2	78	37
2	4 1/2	64	49
3	4 1/2	69	39
4	4 1/2	79	48

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 6

CORE LENGTH (INCHES)

BACKGROUND (cpm) 112 Am^{241} 165 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	939	541
2	1/2	1254	886
3	1/2	1554	1317
4	1/2	1148	634
1	2 1/2	342	302
2	2 1/2	335	443
3	2 1/2	342	430
4	2 1/2	194	322
1	4 1/2	168	181
2	4 1/2	135	235
3	4 1/2	121	183
4	4 1/2	176	337

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 6-A

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 126 Am^{241} 173 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	29	8
2	1/2	7	49
3	1/2	60	62
4	1/2	18	9
1	2 1/2		
2	2 1/2		
3	2 1/2		
4	2 1/2		
1	4 1/2		
2	4 1/2		
3	4 1/2		
4	4 1/2		

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 6-B

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 108 Am^{241} 159 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	320	465
2	1/2	253	217
3	1/2	373	261
4	1/2	436	430
1	2 1/2	124	104
2	2 1/2	109	120
3	2 1/2	113	94
4	2 1/2	85	73
1	4 1/2	109	113
2	4 1/2	136	122
3	4 1/2	120	102
1	4 1/2	97	108

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 7

CORE LENGTH (INCHES)

BACKGROUND (cpm) 110 Am^{241} 143 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	280	200
2	1/2	262	212
3	1/2	243	202
4	1/2	284	282
1	2 1/2	740	511
2	2 1/2	461	227
3	2 1/2	446	445
4	2 1/2	645	383
1	4 1/2	168	250
2	4 1/2	114	110
3	4 1/2	120	85
4	4 1/2	131	180

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 7-A

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 118 Am^{241} 142 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	345	83
2	1/2	364	117
3	1/2	458	253
4	1/2	361	112
1	2 1/2	862	453
2	2 1/2	732	381
3	2 1/2	690	397
4	2 1/2	1062	1097
1	4 1/2	326	321
2	4 1/2	191	145
3	4 1/2	207	169
4	4 1/2	247	284

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 7-B

CORE LENGTH (INCHES) 30

BACKGROUND (cpm) 131 Am^{241} 176 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	117	98
2	1/2	158	107
3	1/2	191	159
4	1/2	162	135
1	2 1/2	235	387
2	2 1/2	176	238
3	2 1/2	215	323
4	2 1/2	361	1072

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 8

CORE LENGTH (INCHES)

BACKGROUND (cpm) 132 Am^{241} 183 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	267	145
2	1/2	262	108
3	1/2	229	140
4	1/2	260	146
1	2 1/2	2050	879
2	2 1/2	1406	354
3	2 1/2	1609	679
4	2 1/2	1777	699
1	4 1/2	644	697
2	4 1/2	335	184
3	4 1/2	576	545
4	4 1/2	1004	1750
1	6 1/2	174	285
2	6 1/2	118	159
3	6 1/2	162	146
4	6 1/2	141	193
1	8 1/2	89	143
2	8 1/2	94	100
3	8 1/2	101	113
4	8 1/2	90	73

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 8-7

CORE LENGTH (INCHES)

BACKGROUND (cpm) 123 Am^{241} 166 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	905	502
2	1/2	897	543
3	1/2	1012	953
4	1/2	957	552
1	2 1/2	548	528
2	2 1/2	525	820
3	2 1/2	330	441
4	2 1/2	536	632
1	4 1/2	134	206
2	4 1/2	138	104
3	4 1/2	149	187
4	4 1/2	137	202
1	6 1/2	123	107
2	6 1/2	168	200
3	6 1/2	[illegible]	114
4	6 1/2	152	169

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 8-B

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 148 Am^{241} 159 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	0	24
2	1/2	15	38
3	1/2	6	51
4	1/2	0	33
1	2 1/2	66	112
2	2 1/2	39	84
3	2 1/2	38	45
4	2 1/2	59	79
1	4 1/2	83	110
2	4 1/2	77	91
3	4 1/2	93	119
4	4 1/2	86	85

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 9

CORE LENGTH (INCHES)

BACKGROUND (cpm) 137 Am^{241} 194 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	4614	2976
2	1/2	10889	3947
3	1/2	4829	2135
4	1/2	3092	1384
1	2 1/2	845	1146
2	2 1/2	819	1461
3	2 1/2	790	2079
4	2 1/2	830	1863
1	4 1/2	563	1456
2	4 1/2	423	682
3	4 1/2	354	868
4	4 1/2	393	912
1	6 1/2	490	1419
2	6 1/2	286	555
3	6 1/2	176	248
4	6 1/2	276	657
1	8 1/2	128	263
2	8 1/2	116	117
3	8 1/2	130	97
4	8 1/2	141	187

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 9-A

CORE LENGTH (INCHES)

BACKGROUND (cpm) 145 Am^{241} 204 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	192	131
2	1/2	152	142
3	1/2	168	135
4	1/2	188	124
1	2 1/2	797	539
2	2 1/2	968	284
3	2 1/2	706	239
4	2 1/2	755	281
1	4 1/2	2049	872
2	4 1/2	2343	1087
3	4 1/2	2486	1136
4	4 1/2	2295	839
1	6 1/2	1529	778
2	6 1/2	1869	1048
3	6 1/2	1502	926
4	6 1/2	1290	511
1	8 1/2	220	105
2	8 1/2	230	117
3	8 1/2	165	81
4	8 1/2	169	98

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 10

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 142 Am^{241} 216 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	423	206
2	1/2	622	367
3	1/2	528	230
4	1/2	517	213
1	2 1/2	1192	1202
2	2 1/2	800	654
3	2 1/2	462	256
4	2 1/2	602	377
1	4 1/2	188	241
2	4 1/2	177	231
3	4 1/2	188	194
4	4 1/2	160	196
1	6 1/2	173	234
2	6 1/2	137	134
3	6 1/2	154	222
4	6 1/2	140	1[illegible]1
1	8 1/2	131	118
2	8 1/2	134	115
3	8 1/2	142	180
4	8 1/2	128	112

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 10-A

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 103 Am^{241} 170 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	40	4
2	1/2	62	61
3	1/2	38	20
4	1/2	158	42
1	2 1/2	146	56
2	2 1/2	154	95
3	2 1/2	149	75
4	2 1/2	146	53
1	4 1/2	650	142
2	4 1/2	730	130
3	4 1/2	909	157
4	4 1/2	786	124

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 10-B

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 122 Am^{241} 158 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	1219	864
2	1/2	1283	1164
3	1/2	1318	1068
4	1/2	1183	965
1	2 1/2	977	687
2	2 1/2	1100	717
3	2 1/2	1199	675
4	2 1/2	1272	708
1	4 1/2	140	189
2	4 1/2	109	128
3	4 1/2	109	131
4	4 1/2	122	146

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 10-B-2

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 103 Am^{241} 149 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	796	545
2	1/2	684	719
3	1/2	728	389
4	1/2	787	500
1	2 1/2	265	329
2	2 1/2	224	417
3	2 1/2	329	572
4	2 1/2	180	515
1	4 1/2	113	166
2	4 1/2	121	158
3	4 1/2	143	266
4	4 1/2	195	476
1	6 1/2	91	110
2	6 1/2	100	151
3	6 1/2	114	135
4	6 1/2	104	175

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 11

CORE LENGTH (INCHES) 48

BACKGROUND (cpm) 101 Am^{241} 139 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	328	136
2	1/2	320	136
3	1/2	398	257
4	1/2	258	95
1	2 1/2	423	547
2	2 1/2	493	539
3	2 1/2	264	242
4	2 1/2	298	301
1	4 1/2	124	168
2	4 1/2	120	179
3	4 1/2	169	364
4	4 1/2	191	319
1	6 1/2	111	140
2	6 1/2	123	214
3	6 1/2	120	136
4	6 1/2	120	134

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 11-B

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 134 Am^{241} 174 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	531	202
2	1/2	1146	622
3	1/2	885	579
4	1/2	463	265
1	2 1/2	203	135
2	2 1/2	265	333
3	2 1/2	278	328
4	2 1/2	223	144
1	4 1/2	125	187
2	4 1/2	146	307
3	4 1/2	114	213
4	4 1/2	129	209
1	6 1/2	76	78
2	6 1/2	85	73
3	6 1/2	8[illegible]	94
4	6 1/2	114	137

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 12

CORE LENGTH (INCHES) 48

BACKGROUND (cpm) 124 Am^{241} 164 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	68	732
2	1/2	969	697
3	1/2	628	380
4	1/2	733	359
1	2 1/2	261	363
2	2 1/2	262	386
3	2 1/2	259	622
4	2 1/2	48	813
1	4 1/2	119	253
2	4 1/2	99	101
3	4 1/2	144	218
4	4 1/2	115	215
1	6 1/2	110	139
2	6 1/2	143	190
3	6 1/2	100	105
4	6 1/2	107	139

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 12-A

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 148 Am^{241} 222 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	63	0
2	1/2	66	0
3	1/2	78	0
4	1/2	66	3
1	2 1/2	101	76
2	2 1/2	142	58
3	2 1/2	120	30
4	2 1/2	107	32
1	4 1/2		
2	4 1/2		
3	4 1/2		
4	4 1/2		

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 12-B

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 128 Am^{241} 161 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	1285	488
2	1/2	1315	493
3	1/2	2575	467
4	1/2	2021	745
1	2 1/2	1055	546
2	2 1/2	1199	402
3	2 1/2	1687	663
4	2 1/2	1224	483
1	4 1/2	185	308
2	4 1/2	209	205
3	4 1/2	182	188
4	4 1/2	191	248

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 13

CCRE LENGTH (INCHES)

BACKGROUND (cpm) 134 Am^{241} 151 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	1858	859
2	1/2	2532	817
3	1/2	2426	825
4	1/2	2237	1366
1	2 1/2	1404	1384
2	2 1/2	744	495
3	2 1/2	855	483
4	2 1/2	1734	2518
1	4 1/2	182	382
2	4 1/2	125	189
3	4 1/2	153	239
4	4 1/2	185	445
1	6 1/2	215	161
2	6 1/2	125	136
3	6 1/2	91	137
4	6 1/2	100	156

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 13-A

CORE LENGTH (INCHES)

BACKGROUND (cpm) 133 Am^{241} 173 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	753	619
2	1/2	608	385
3	1/2	532	339
4	1/2	640	417
1	2 1/2	986	648
2	2 1/2	941	560
3	2 1/2	1045	396
4	2 1/2	878	338
1	4 1/2	3534	1529
2	4 1/2	3612	1462
3	4 1/2	3141	1125
4	4 1/2	2834	1176
1	6 1/2	1180	510
2	6 1/2	993	442
3	6 1/2	823	267
4	6 1/2	1079	554
1	8 1/2	134	109
2	8 1/2	157	169
3	8 1/2	148	121
4	8 1/2	121	105

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 13-B

CORE LENGTH (INCHES)

BACKGROUND (cpm) 134 Am^{241} 181 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	1536	815
2	1/2	2042	980
3	1/2	1730	943
4	1/2	1652	1493
1	2 1/2	4474	4182
2	2 1/2	3875	1611
3	2 1/2	3877	1053
4	2 1/2	5709	6318
1	4 1/2	434	719
2	4 1/2	274	290
3	4 1/2	328	472
4	4 1/2	381	448
1	6 1/2	177	290
2	6 1/2	272	796
3	6 1/2	179	383
4	6 1/2	135	230
1	8 1/2	82	87
2	8 1/2	130	267
3	8 1/2	120	115
4	8 1/2	96	95

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 14

CORE LENGTH (INCHES) 48

BACKGROUND (cpm) 142 Am^{241} 202 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	3	0
2	1/2	0	0
3	1/2	0	0
4	1/2	0	0
1	2 1/2	10	21
2	2 1/2	12	0
3	2 1/2	19	2
4	2 1/2	14	4
1	4 1/2	26	26
2	4 1/2	31	49
3	4 1/2	11	33
4	4 1/2	12	27

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 14-A

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 127 Am^{241} 171 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	814	616
2	1/2	923	1570
3	1/2	867	354
4	1/2	910	417
1	2 1/2	1190	773
2	2 1/2	1174	576
3	2 1/2	1177	707
4	2 1/2	120[illegible]	439
1	4 1/2	1136	573
2	4 1/2	732	410
3	4 1/2	963	604
4	4 1/2	2089	2376
1	6 1/2	144	110
2	6 1/2	158	141
3	6 1/2	152	91
4	6 1/2	165	142

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 14-B

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 134 Am^{241} 167 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	100	83
2	1/2	91	86
3	1/2	86	121
4	1/2	87	171
1	2 1/2	79	119
2	2 1/2	101	112
3	2 1/2	119	236
4	2 1/2	134	192

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 15

CORE LENGTH (INCHES) 48

BACKGROUND (cpm) 133 Am^{241} 167 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	349	280
2	1/2	452	399
3	1/2	472	322
4	1/2	427	314
1	2 1/2	643	220
2	2 1/2	748	478
3	2 1/2	773	422
4	2 1/2	814	523
1	4 1/2	173	182
2	4 1/2	158	250
3	4 1/2	135	229
4	4 1/2	198	337

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 15-A

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 149 Am^{241} 194 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	72	146
2	1/2	84	74
3	1/2	78	93
4	1/2	92	111
1	2 1/2	106	105
2	2 1/2	118	89
3	2 1/2	136	184
4	2 1/2	172	301
1	4 1/2	123	109
2	4 1/2	69	36
3	4 1/2	134	205
4	4 1/2	131	191

SOIL CORE EVALUATION DATA

CLEAN SLATE III EVENT DATE

CORE NO. 15-B

CORE LENGTH (INCHES) 36

BACKGROUND (cpm) 152 Am^{241} 195 Pu^{239}

REMARKS:

QUADRANT	DISTANCE FROM TOP(INCHES)	NET Am^{241} COUNT	NET Pu^{239} COUNT
1	1/2	18	40
2	1/2	42	42
3	1/2	20	29
4	1/2	13	0
1	2 1/2	110	94
2	2 1/2	58	43
3	2 1/2	69	39
4	2 1/2	90	83
1	4 1/2	108	121
2	4 1/2	131	136
3	4 1/2	116	106
4	4 1/2	137	104

APPENDIX B

CALCULATION OF BELT MONITOR EFFICIENCY

Let:

E_{20} = efficiency for Am^{241} mixed with soil 20 inches wide on the belt, cpm/ c

E_{24} = efficiency for Am^{241} mixed with soil 24 inches wide on the belt, cpm/ c

E_x = average efficiency for four quadrants at a distance x from the center of the belt area viewed by the detector, cpm/ c

A_x = area in cm^2 of concentric ring 2 inches wide with inner edge x inches from the center of the belt viewed by the detector

S_a = self-absorption factor for Am^{241} gamma = 0.77 based on data in Table 2.6

$$E_{20} \quad \frac{\frac{(E_x + E_{x+2})}{2} A_x}{2026 \text{ cm}^2}$$

with x ranging from 0 to 8 inches in 2-inch increments

$$E_{24} \quad \frac{\frac{(E_x + E_{x+2})}{2} A_x}{2920 \text{ cm}^2}$$

with x ranging from 0 to 10 inches in 2-inch increments

F_{20} = factor to convert belt Am^{241} net cpm to g Pu/kg of soil

$$= \frac{15 \text{ g Pu}/\mu c \text{ Pu}}{(E_{20})(0.77 S_a)(0.01319 \mu c \text{ Am}/\ c \text{ Pu})(18.3 \text{kg soil})}$$

$= 81/E_{20}$

F_{24} = factor to convert belt Am^{241} net cpm to g Pu/kg of soil

$$F_{24} = \frac{15 \mu g \text{ Pu}/\mu c \text{ Pu}}{(E_{24})(0.77 S_a)(0.01319\ c \text{ Am}/\ c \text{ Pu})(22.0 \text{kg soil})}$$

$= 67/E_{24}$

From Table 2.5:

E_0 = 519 cpm/0.702μc = 737 cpm/μc

E_2 = 513 cpm/0.702μc = 728 cpm/μc

E_4 = 514 cpm/0.702μc = 730 cpm/μc

E_8 = 412 cpm/0.702μc = 585 cpm/μc

E_8 = 368 cpm/0.702μc = 522 cpm/μc

E_{10} = 275 cpm/0.702μc = 391 cpm/μc

E_{12} = 196 cpm/0.702μc = 278 cpm/μc

$$A_0 = \text{pi}\ (5.08)^2 = 81\ \text{cm}^2$$

$$A_2 = \text{pi}\ (10.16)^2 - A_0 = 324 - 81 = 243\ \text{cm}^2$$

$$A_4 = \text{pi}\ (15.24)^2 - A_2 = 730 - 324 = 406\ \text{cm}^2$$

$$A_6 = \text{pi}\ (20.32)^2 - A_4 = 1297 - 730 = 567\ \text{cm}^2$$

$$A_8 = \text{pi}\ (25.4)^2 - A_6 = 2026 - 1297 = 729\ \text{cm}^2$$

$$A_{10} = \text{pi}\ (30.48)^2 - A_8 = 2920 - 2026 = 894\ \text{cm}^2$$

$$\frac{(E_0 + E_2)}{2}(A_0) = \frac{(737 + 728)}{2}(81) = 59{,}292$$

$$\frac{(E_2 + E_4)}{2}(A_2) = \frac{(728 + 730)}{2}(243) = 177{,}147$$

$$\frac{(E_4 + E_6)}{2}(A_4) = \frac{(730 + 585)}{2}(406) = 267{,}148$$

$$\frac{(E_6 + E_8)}{2}(A_6) = \frac{(585 + 522)}{2}(567) = 314{,}118$$

$$\frac{(E_8 + E_{10})}{2}(A_8) = \frac{(522 + 391)}{2}(1216) = 555{,}104$$

$$\frac{(E_{10} + E_{12})}{2}(A_{10}) = \frac{(391 + 278)}{2}(894) = 299{,}490$$

$$E_{20} = \frac{59{,}292 + 177{,}147 + 267{,}148 + 314{,}118 + 555{,}104}{2026}$$

$$= 1{,}372{,}809/2026 = 678\ \text{cpm}/\mu c$$

$$E_{24} = \frac{1{,}372{,}809 + 299{,}490}{2920} = 573\ \text{cpm}/\mu c$$

$$F_{20} = 81/678 = 0.12 \frac{\mu g\ \text{Pu/kg soil}}{\text{belt cpm Am}^{241}}$$

$$F_{24} = 67/573 = 0.12 \frac{\mu g\ \text{Pu/kg soil}}{\text{belt cpm Am}^{241}}$$

APPENDIX C

EVALUATION OF ALUMINUM DEBRIS

The metal debris originally recovered post-detonation was limited to small pieces to facilitate gamma counting and laboratory analysis. It was learned later that these samples were of aluminum, not iron, and therefore from the device stands, not the storage igloo. However, preliminary calculations indicated significant Pu scavenging on aluminum, so this phase of the program was continued.

Two thicknesses of aluminum, 0.250 inch and 0.120 inches, were used in fabricating the base and upright portions of the device stands. The respective areas of each thickness, 626 in^2 and 614 in^2 were used in calculating total scavenging. This design data and other information on device stands were obtained from Reference 5.

CLEAN SLATE I

Evaluation of Aluminum Debris

Sample No.	ug Pu by γ Count	ug Pu by Rad Chem	Thickness Inches	Area in^2	ug Pu/in^2
160- 1	15		0.12	2.4	6
2	<5		0.12	1.6	<3
3	370		0.25	1.4	264
4	520		0.12	1.6	330
5	<5		0.12	1.2	<4
6	16		0.25	1.7	9
7	180	205	0.25	0.4	450
8	<5		0.25	1.2	<4
9	750	720	0.25	1.6	469
10	370		0.25	0.8	463
11	<5		0.25	0.6	<8
12	65		0.12	1.4	46
13	<5		0.12	3.2	<2
14	4600		0.12	3.2	1400

Mean 250
Mean of 0.12" thickness 250
Mean of 0.25" thickness 240

$$(10^{-6})\ (250\ ug/in^2)\ (614\ in^2)\ (9\ \text{stands}) = 1.4\ g$$

$$(10^{-6})\ (240\ ug/in^2)\ (626\ in^2)\ (9\ \text{stands}) = \underline{1.4\ g}$$

TOTAL 2.8 g

CLEAN SLATE II

Evaluation of Aluminum Debris

Sample No.	ug Pu by γ Count	ug Pu by Rad Chem	Thickness Inches	Area in^2	ug Pu/in^2
159-A	Bkg		0.12	20	--
B	18,900	24,800	0.12	12	1,500
C	1,500		0.12	6	300
D	100,800	96,600	0.12	24	4,200
E	6,200		0.12	20	300
F	30,600		0.25	32	1,000
G	Bkg		0.25	16	--
H	12,000		0.25	25	500
I	3,500		0.12	16	200
J	13,500		0.12	--	--
K	Bkg		0.12	20	--
L	1,300		0.12	8	200
M	4,100		0.12	16	300
N	9,000		0.12	12	800
O	Bkg		0.12	6	--
P	1,100		0.12	8	100
Q	20,700		0.12	6	3,500
R	8,200		0.12	15	500
S	23,000		0.12	12	1,900
T	1,300		0.12	4	300

Mean 780
Mean of 0.12" thickness 830
Mean of 0.25" thickness 500

(10^{-6}) (830 ug/in^2) (614 in^2) (19) = 9.7 g

(10^{-6}) (500 ug/in^2) (626 in^2) (19) = 6.0 g

TOTAL 15.7 g

CLEAN SLATE III

Evaluation of Aluminum Debris

Sample No.	ug Pu by γ Count	ug Pu by Rad Chem	Thickness Inches	Area in^2	ug Pu/in^2
163-A	24,300		0.12	18	1,400
B	14,900		0.12	4	3,700
C	10,100	8,200	0.25	9	1,100
D	900		0.25	8	100
E	20,300		0.12	8	2,500
F	8,800		0.12	6	1,500
G	1,600		0.12	6	300
H	1,700		0.25	6	300
I	900		0.25	2.2	400
J	1,400		0.25	3.0	500
K	10,100	8,900	0.12	2.0	500
L	200		0.12	1.0	200
M	800		0.25	1.5	500
N	6,800		0.12	2.5	2,700
O	150		0.12	3.0	50
P	500		0.12	1.5	300
Q	600		0.12	2.0	300
R	90		0.12	1.0	90
S	400		0.25	1.5	300
T	300		0.25	2.2	100

Mean all pieces	840
Mean (0.12" thick)	1,130
Mean (0.25" thick)	330

(10^{-6}) $(1130\ ug/in^2)$ $(614\ in^2)$ (19 stands) = 13.2 g

(10^{-6}) $(330\ ug/in^2)$ $(626\ in^2)$ (19 stands) = 3.9 g

TOTAL 17.1 g

REFERENCES

1. F. Wilcox and L. Brown, Reynolds Electrical and Engineering Co., Inc., Mercury, Nevada; personal communications (1962/1963).

2. H. Eberline, Eberline Instrument Corporation, Santa Fe, New Mexico; personal communication (1962).

3. W. Johnson, Sr.; "Alpha Survey"; Project 2.5, Operation Roller Coaster, POR-2505; Eberline Instrument Corporation, Santa Fe, New Mexico; Official Use Only.

4. F. Schonfeld, Los Alamos Scientific Laboratory, Los Alamos, New Mexico; personal communication (1963).

5. W. Holder, Sandia Corporation, Albuquerque, New Mexico; letter to: E. Geiger, Eberline Instrument Corporation, Santa Fe, New Mexico; Subject: "Roller Coaster Device Support Stands," 12 November 1963; Unclassified.